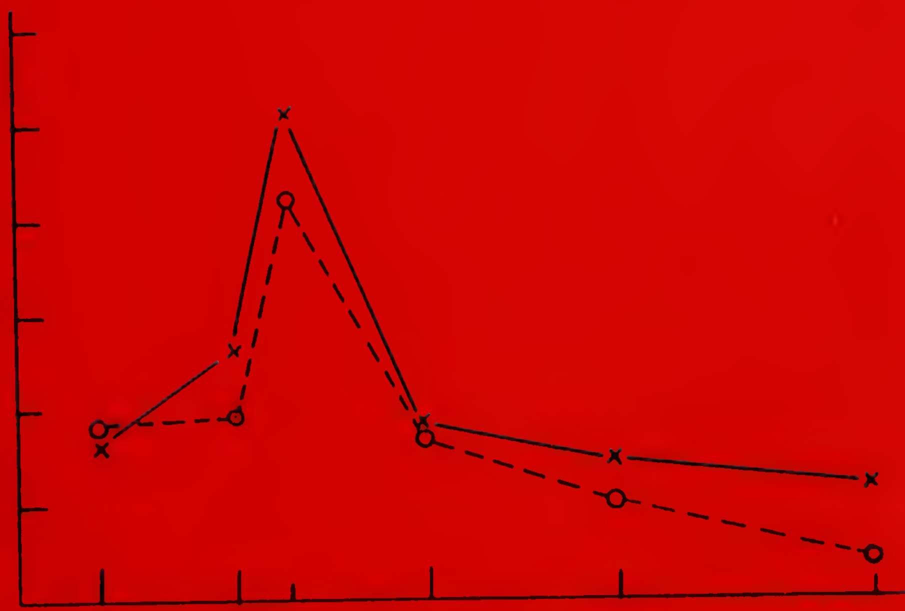
RESEARCH BULLETIN



Number 1 January 1962

AMERICAN FOUNDATION FOR THE BLIND
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Compiled by the

DIVISION of RESEARCH and STATISTICS

AMERICAN FOUNDATION FOR THE BLIND

15 WEST 16 STREET NEW YORK 11, N.Y

Price $2.50 per issue

Introducing the Research Bulletin

To serve the blind we must know what we are doing and why we are doing it. Knowledge is gained through research.

The American Foundation for the Blind recognizes the urgent need for more research into all phases of work for the blind. To further such research we must keep abreast of what has been done and of current investigations and experiments.

We are therefore proud to initiate this new service, a Research Bulletin to inform the research-minded and also to stimulate further inquiries into a vast and largely untracked field.

The Bulletin will appear from time to time according to whenever the Division of Research and Statistics has on hand suitable current material about which information is needed.

Comments about the new service will be welcome.

M. Robert Barnett
Executive Director

Prefatory Note

The American Foundation for the Blind, as a matter of course, peruses and evaluates a considerable number of articles, reports and manuscripts. Students occasionally submit their thesis or dissertation for possible publication. A Foundation staff member often encounters a research report or statistics which in his opinion merits wider dissemination. In some cases the Foundation initiates or contracts for a research project and is naturally interested in publishing the findings.

Of these various papers, a few may be fortunate enough to find their way into journals not widely circulated. Others, because of their subject matter or length, may never be published.

For this reason, the Division of Research and Statistics of the American Foundation for the Blind publishes a Research Bulletin, composed both of original manuscripts and of previously published articles. The Research Bulletin appears from time to time and contains sociological, psychological and technological papers of interest primarily to research personnel, and secondarily to those interested in the general improvement of services to the visually handicapped.

Personnel of the Division of Research and Statistics, together with other specialists on the Foundation staff, constitutes an informal editorial board. Papers must be either directly or indirectly relevant to some aspect or problem of visual impairment, and must meet generally accepted research criteria. Since these are the only standards for selection, the articles published herein do not necessarily reflect the opinion of the Trustees and Staff of the American Foundation for the Blind.

We earnestly solicit contributions from all scientific fields and welcome all reaction to published articles.

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IDENTIFYING AND TEACHING

AUDITORY CUES FOR TRAVELING IN THE BLIND

EDITOR'S NOTE:

This paper represents the Introduction and Sections 2 and 5 from the last progress report in the project of the above title at the C.W. Shilling Auditory Research Center, Inc., Groton, Connecticut.

This three-year project is supported by the Office of Vocational Rehabilitation and The Seeing Eye, Inc., Morristown, New Jersey. Copies of the complete report are available from the Division of Research and Statistics of the American Foundation for the Blind as long as the supply lasts.

INTRODUCTION

J. K. Dupress

The principal goals of this project are:

1) To study differences between the capabilities of good and poor travelers with particular reference to auditory task performance.

2) To provide tests which measure individual differences in mobility capability which can then be used in rehabilitation centers.

3) To develop training tapes which can be incorporated into existing mobility training programs.

Considerable progress has been made in the past six months covered by this report toward each of these goals. A fairly complete interview and test battery have been prepared.

As this report is being written, testing has begun and duplicates of the training tape have been forwarded to other organizations.

II

MOBILITY SCALE

H.N. Wright

EDITOR'S NOTE:

There has been some misunderstanding concerning the intent of the Shilling researchers in their use of the word <u>competency</u> in the following part of their report. Competency is not intended to mean excellence of task performance. Rather the use of the word

competency in the Mobility Scale involves individual psychological and sensory attributes required for mobility with a minimum of assistance. For example, the successful and rapid location of a specific objective in a complex and unfamiliar environment is best achieved with a reasonably intelligent sighted guide. It requires more individual skill on the part of the blind person to attain the same objective with a dog guide or a cane.

As the research continues in the Shilling project it is hoped that criteria can be established to measure task performance. In the meantime the Mobility Aids Scale must suffice for screening purposes.

Mobile blind individuals frequently are classified both by themselves and rehabilitation counselors as "good travelers" or "poor travelers". Those who travel only in their home and its surroundings are classified as "homebound". Although such descriptions are useful in some circumstances, they are too vague to permit a well-defined classification of mobility competency. The purpose of this investigation was to develop a mobility scale so that blind travelers could be systematically classified on an ordered scale.

Requirements. Two requirements for the mobility scale were: (1) it should be applicable to all blind, and (2) it should be based on what the blind individual does, not on his intent. The type of scale developed within these two requirements is ordinal. No assumption is made about the distance between the values on the scale. *

Assumptions. The mobility scale designed to meet the requirements set forth above rests on four assumptions. Each assumption describes scale relations which, when combined, permit the construction of the mobility scale.

Assumption 1: Traveling indicates a greater degree of mobility competency than not traveling.

Those blind individuals who restrict their traveling to their own home are not considered mobile. By traveling we simply mean going from one place to another, usually with a purpose.

Assumption 2: Traveling in unfamiliar environments indicates a greater degree of mobility competency than traveling in familiar environments.

The criterion for familiarity is based, in part, on predictability. By a familiar environment is meant an area in which only the minor aspects change; a certain degree of uncertainty is introduced over which the traveler has no control. For example, the route from a blind traveler's house to a nearby store might be classified as a familiar environment. An unfamiliar environment is one in which the traveler has never been.

Assumption 3: Travel competency can be ordered on a dimension of dependency. Such a scale from no dependency to complete dependency is:

1. none
2. cane
3. guide dog
4. companion

The above four-point scale includes the most common modes of assistance used by blind travelers. The amount of assistance used by a blind individual, however, may be determined by the type of environment in which he is traveling.

* See W. S. Torgerson, "Theory and Methods of Scaling" (John Wiley & Sons, 1958) for a recent discussion of scaling procedures.

Assumption 4: A blind person will not travel with less assistance in an unfamiliar environment than in a familiar environment.

The issumption applies to those blind individuals who travel; and is related to assumptions 2 and 3. Ten combinations that relate the amount of assistance to each kind of environment are shown in figure II-1. The connecting lines represent all the possible combinations under this assumption.

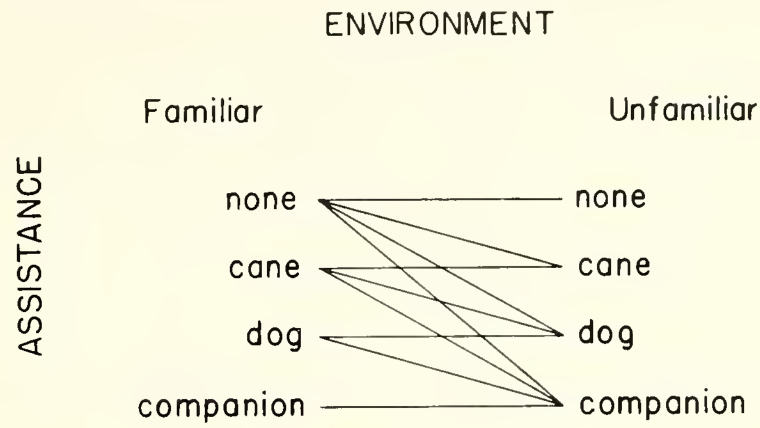

Figure II-1
The relation between amount of assistance and kind of environment under assumption 4

Mobility Scale

1. travels in familiar environments with no assistance
   travels in unfamiliar environments with no assistance

2. travels in familiar environments with no assistance
   travels in unfamiliar environments with a cane

3. travels in familiar environments with no assistance
   travels in unfamiliar environments with a guide dog

4. travels in familiar environments with no assistance
   travels in unfamiliar environments with companion

5. travels in familiar environments with a cane
   travels in unfamiliar environments with a cane

6. travels in familiar environments with a cane
   travels in unfamiliar environments with a guide dog

7. travels in familiar environments with a cane
   travels in unfamiliar environments with a companion

8. travels in familiar environments with a guide dog
   travels in unfamiliar environments with a guide dog

9. travels in familiar environments with a guide dog
   travels in unfamiliar environments with a companion

10. travels in familiar environments with a companion
travels in unfamiliar environments with a companion

11. travels in familiar environments with no assistance
does not travel in unfamiliar environments

12. travels in familiar environments with a cane
does not travel in unfamiliar environments

13. travels in familiar environments with a guide dog
does not travel in unfamiliar environments

14. travels in familiar environments with a companion
does not travel in unfamiliar environments

15. does not travel in familiar environments
does not travel in unfamiliar environments

Results. The 15-point mobility scale was constructed from the foregoing assumptions. Successive degrees of mobility are ordered from the greatest degree to the least degree of mobility competency.

Validation. Although the assumptions used to obtain the mobility scale are reasonable, their combined use might introduce some systematic effects which could disrupt the relative position of some scale values. Validation of the scale was accomplished by a paired comparisons technique.

Procedure: The description of each scale position was paired twice with all others, the second time opposite in order to the first. Such pairing of the fifteen scale positions yielded 210 pairs. These pairs were presented singly to five judges in a different random order to each. The judges were asked which of the two scale descriptions they received represented, in their opinion, the greatest degree of mobility competency. The results from these comparisons were then correlated with the mobility scale from which the original pairs were drawn. High and significant correlations between the judges' ratings and the logically derived scale indicate that the mobility scale as defined previously is valid.

Five judges were used in this validation. Two judges were blind travelers; one used a cane, and the second used a guide dog. Of the three sighted judges; the first was associated with research on problems of the blind, the second was a counsellor in a rehabilitation center for the blind, and the third had no association with the blind whatsoever.

Results: The scale positions for each judge are shown in Table 1. All the correlations are significant at less than the .01 level of confidence. The average rank order correlation coefficient for all judges was .91, and means that the scale previously derived is a valid indication of mobility competency.

Summary. A 15-point scale of mobility competency was developed so that blind individuals could be systematically evaluated on their degree of travel skill for both research and clinical purposes. This scale was found to be a valid indication of the degree of mobility competency by a representative panel of five judges.

Table I

Rank order and correlation of each judge with the scale of mobility competency.

Basic Scale Rank	Scale Position Derived from each Judge's Ratings				
	Blind		Sighted		
	cane	dog	counsellor	research	naive
1	8.5	4.5	10.0	1.0	1.0
2	1.0	1.5	1.0	2.0	2.0
3	2.0	1.5	3.0	3.0	3.0
4	5.0	7.0	8.5	6.0	4.0
5	3.0	3.0	2.0	4.0	5.0
6	4.0	4.5	4.0	5.0	6.0
7	6.5	9.0	5.5	7.0	7.5
8	6.5	6.0	5.5	8.0	7.5
9	8.5	8.0	7.0	9.0	9.0
10	10.0	11.5	8.5	10.0	10.0
11	11.0	11.5	12.5	11.0	11.0
12	12.0	11.5	11.0	12.0	12.0
13	13.0	11.5	12.5	13.0	13.0
14	14.0	14.0	14.0	14.0	14.0
15	15.0	15.0	15.0	15.0	15.0
rho	.875	.921	.762	.989	.999

Continuation. There are no plans within this project to continue this aspect further. Our only interest in developing the scale of mobility competency was to define the degree of travel skill of those blind individuals who will participate in this investigation.

V

AUDITORY TRAINING FOR THE BLIND

H. N. Wright and J. K. Dupress

One definition of auditory training is the use of techniques to improve an individual's ability to identify sounds not previously recognized. Although such techniques have long been used with the hearing impaired, they have not been systematically applied to the blind to improve their mobility. The reason for this development is perhaps because the purpose of such training is different for each of these groups of individuals.

The purpose of auditory training for the hearing impaired is to improve the use of residual hearing so that most of what is said is identified. The purpose of auditory training for the blind, however, is to improve orientation by obstacle detection and identification. This difference in purpose requires a different analytical approach to the problem of training, even though some of the techniques are common to both of these groups of individuals.

In all auditory training techniques, the listener proceeds from easy to more difficult sound discriminations. When a given degree of competency in discrimination is accomplished, the ability to identify sounds not previously recognized as different from each other is improved. The limit of an individual's ability to identify different sounds is determined by the degree to which he discriminates among different kinds of sounds. An analy-

sis of the requirements for a complete auditory training program for the blind is developed below, after a discussion of the general techniques already found useful for the hearing impaired.

General Techniques. Easy to more difficult sound discriminations are obtained by gross to fine differences among sounds. Although the ease of discriminating among most sounds depends upon hearing status, the way in which gross to fine differences are produced does not. The complexity of sounds is varied by changing (1) spectrum and (2) temporal pattern. The third variation in complexity is the transitional properties produced by a combination of spectrum changes and temporal pattern.

A simple spectrum contains a single frequency at some intensity. Such a spectrum has a definite pitch and loudness. More complex spectra are produced by adding more frequencies and have, in addition to loudness, a definite quality. Different temporal patterns are produced by varying the duration of successive sounds and the silent interval between each. The spectrum changes accompanying such variations provide transitional information.

Discrimination among sounds that differ in all of the above three aspects is easy. More difficult discriminations are obtained by reducing the number and degree of these differences.

Principles for the Blind. The techniques of auditory training for the blind are identical to those used with the hearing impaired for the detection and identification of those obstacles that act as a sound source. Since the purpose of the training is different, however, two additional considerations are necessary: (1) sound shadow and (2) sound echo.

A framework, or theoretical model, useful for analyzing those parameters necessary for a systematic approach to a method of auditory training for the blind has, therefore, three levels of complexity. These levels are shown as separate cases in Figure V-1.

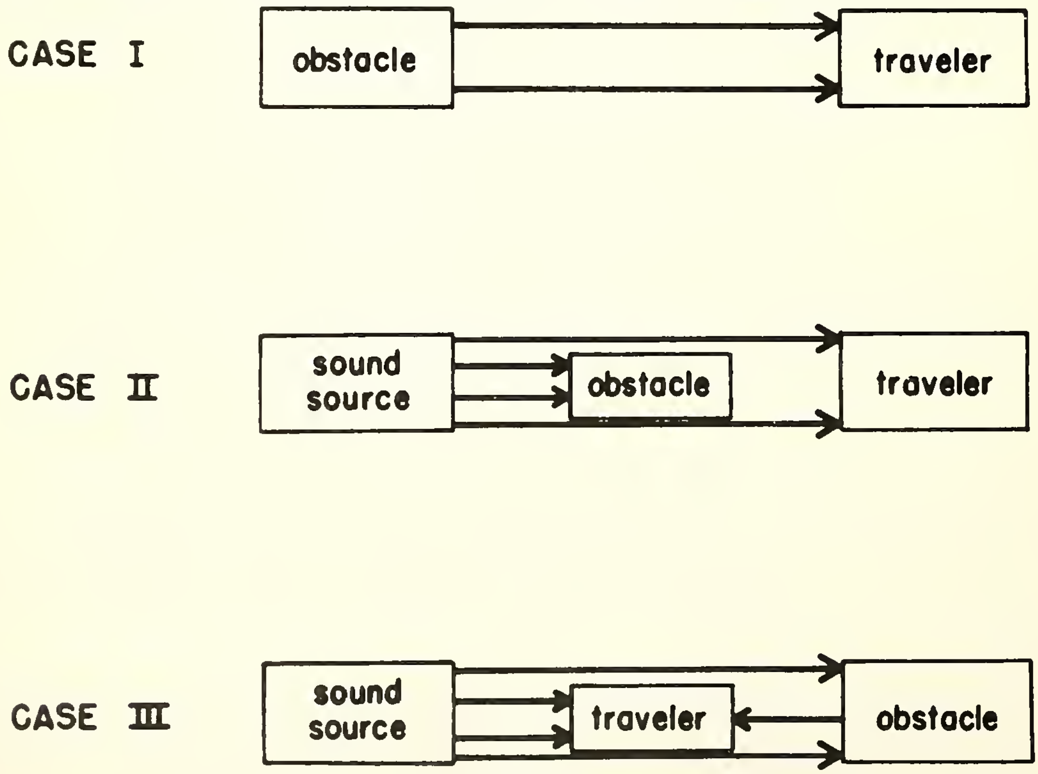

Figure V-1
Theoretical model for analyzing the parameters necessary for a systematic approach to a method of auditory training for the blind

Case I is the identification of an obstacle by the sound it produces. The most important obstacles that act as a sound source are automobiles, trucks, and buses. Other obstacles that are easily identified by the sound they produce are people (by their footfalls and talking) and perambulators. The detection of obstacles in this case depends upon 1) the spectrum of the sound source and 2) the distance of the traveler from the obstacle.

Case II is the detection of an obstacle by the sound shadow it produces. The quality of a sound changes when an obstacle is placed between the observer and the sound source because the obstacle blocks the higher frequencies much in the same way as it blocks light. Two examples of such obstacles are telephone poles and parked automobiles. The detection of obstacles in this case depends upon: 1) the spectrum of the sound source, 2) the size of the obstacle, 3) the distance of the traveler from the obstacle, and 4) the distance of the obstacle from the sound source.

Case III is the detection of an obstacle by the sound echo it produces. The best example of such an obstacle is a building. Changes in the building line, say a store entrance, can be detected by changes in the sound echo. The detection of obstacles in this case depend upon: 1) the spectrum of the sound source, 2) the size of the obstacle, 3) the composition of the obstacle, 4) the distance of the traveler from the obstacle, and 5) the distance of the obstacle from the sound source.

Conclusion. From the above framework, we can easily see why auditory training for the blind is not simple. All three cases considered in the model can, and most often do, occur simultaneously under different spatial relations. Since blind travelers frequently make their auditory judgments while moving, they constantly change the varying sounds that reach their ears. This double change (changing sounds, changing position), coupled with the three separate types of considerations for analysis, increases the difficulty for the blind traveler of obtaining consistent auditory information. An auditory training program for the blind to be most effective should include all the above aspects before it can be considered.

A STUDY OF THE EFFECT OF MOTION SIZE ON PERFORMANCE FOR A TASK INVOLVING KINESTHETIC FEEDBACK

by

William Russell Ferrell

EDITOR'S NOTE:

This paper is based on a Master's Thesis, submitted to the Massachusetts Institute of Technology in 1961. The project was supported in part by a grant-in-aid from the American Foundation for the Blind and sponsored by the Division of Sponsored Research of the M.I.T.

The research described is relevant to the problems of sensory deprivation, because blind people constantly explore and interact with their environment without the benefit of visual feedback.

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Background

In order to extend or improve the capabilities of a human operator engaged in tasks involving manipulation or control, the engineer must seek to adapt the equipment used to the operator's physical and psychological limitations. Essentially what is sought is an easy intimacy between the man and the machine he controls, a projection of his skill and judgment into its mechanical operation. For those machine functions which require a human operator, the machine should be, ideally, an extension of the person. To achieve such a connection between machine and operator, the designer of the system must thoroughly understand the characteristics of the person and those conditions under which he can be expected to give optimum performance.

The present study is principally motivated by the need to design man controlled remote handling and sensing devices which exhibit optimum performance. The primary object has been to examine the effect of the size of hand motion on the performance of a task involving certain aspects of manipulation. In connection with the particular task used, an attempt was also made to determine how performance could be related to the physical constraints of the situation.

The Problem

Of those sensory modes used in manipulation, one of the most complex and most important is the proprioceptive or kinesthetic, which, unlike the more passive senses, is intimately allied with motion itself. Proprioception refers to the reception of stimuli which originate in the muscles, tendons, and joints, and it informs one of the state of motion and position of the limbs relative to the body. In effect, the proprioceptive senses in conjunction with vision and memory define the working space, the region in which manipulation takes place. It is generally true that vision is the arbiter of form in space (8), but proprioception and touch are primitive to it in the sense that it is through their mediation that one learns to interpret visual cues in spatial terms.

The most important information which one obtains from the proprioceptive senses is that of spatial position. This information can be considered from two substantially equivalent points of view, depending on the input. If the hand and arm are considered as a position serve, a desired position as input will result in an output, actual position, more or less accurately reflecting the input. If the input is an actual location, the output is a judged or perceived location. Manipulation involves both of these complementary functions of performance and perception.

Many remote manipulators in industry, especially those that are for complicated work , use the proprioceptive sense of the operator as well as his vision for positioning. This is done by having him insert his hands and arms into appropriate equipment associated with the master unit. The motion of his hands and arms is then duplicated at a distance by the slave unit. To consider a general case of such an arrangement, one may think of the two units linked by an electrical cable. There is no inherent reason why the motion of the slave unit need correspond exactly to that of the master, since, by appropriately altering the signals being sent through the cable, the motion of the slave could be made to correspond to an entirely different mapping of the master motion. In general, one feels certain that such transformations are likely to prove deleterious, but the most obvious class of transformation, simple change of size, deserves consideration.

One would like to be able to answer the question: How is the effectiveness of remote manipulation dependent on the size of the motions required of the operator? For most

practical cases this is tantamount to asking how the effectiveness of the proprioceptive feedback of position depends on the size of the operator's hand motion. This is so because in most cases alteration of size between master and slave units need not appreciably change the situation for senses other than the proprioceptive. The visual properties of the situation would be unchanged except insofar as the operator sees his own hand motions. Since he must generally concentrate on the site of the manipulation, this is likely to have an effect of secondary importance. The other important sense concerned, touch, is not specifically provided for in remote manipulators at present, though a certain amount of information concerning the response of the apparatus is transmitted to the operator through his cutaneous senses. The information obtained in this way has been contaminated and filtered by the mechanical and electrical components and is also likely to contribute only effects of secondary importance. There seems to be good reason to believe that an improvement in proprioceptive feedback alone could lead to an improvement in manipulative effectiveness.

Working Hypothesis

Factors tending to impair performance at both small and large amplitudes of motion could combine to produce a relation between a measure of effectiveness of kinesthetic feedback and extent of the motions involved which has a broad maximum over the middle range of size. The existence of such a relationship is the hypothesis tested in the present study. The hypothesis is based essentially on an analogy to the way differential discrimination is found to vary with stimulus magnitude for a number of senses.

It is common to many perceptual continua that people show a greater sensitivity to relative changes in the magnitude of a stimulus or stimulus dimension when the magnitude is in a certain range. The Weber fraction, $\frac{\Delta I}{I}$, the ratio of just noticeable change of stimulus intensity to intensity, shows a minimum when plotted against intensity for a number of cases such as cutaneous pressure, visual brightness, lifted weights, and taste. (6, p.268) The factors affecting performance quality, discriminations of distance and angle and the like, may be subject to somewhat the same kind of relation, and though a minimum for the Weber fraction is by no means universal, its repeated occurrence would make it a reasonable possibility in the present case.

There is no doubt that the kinesthetic senses are less effective for very small motions. For example, it is well known that the hand writing of those who become blind tends to deteriorate in quality unless they take pains to practice with the help of a sighted person. This is because, for such small motion, information fed back by kinesthesis is not a sufficient index of writing performance.

It is harder to argue that kinesthetic feedback could be less effective for large motions than for those of an intermediate size, but it would seem plausible to suppose, in analogy to most physical systems, that non-linearities or "saturation" effects could appear when movements approach their limiting extent.

Previous Experiments

Several studies show that the size of a motion is significantly related to accuracy. Brown, Knauft, and Rosenbaum (4) considered the situation in which a subject attempts to reproduce, without the help of vision, a distance previously presented visually. The subject moved a sliding pointer in order to reproduce the distance. The authors found that the smaller distances tended to be overestimated and the larger underestimated. But they specifically warn that the distance for which the errors change sign, the indifference point, is not optimum but tend toward the mean of the series of motions involved, citing Hollingworth (13) insupport. The percentage accuracy increased with distance up

to about 10-cm. and was nearly constant thereafter up to the largest motions used, 40-cm. Quite similar results were reported by Weiss (18), who likewise noted a decreasing relative error with increasing distance, and a tendency toward overestimation of relatively smaller motions and underestimation of the larger. With the subject visually monitoring his performance, Brown and Slater-Hammel (5) found that the time required for making corrective motions in indicator setting increased with distance moved from 2.5-cm. to 10-cm. but was the same for 40 as for 10. These results seem to say that motions of 10-cm. or more are likely to be preferable on the basis of their smaller percentage accuracy, but it is not at all clear that extrapolation from this data to a more general situation is warranted.

Manual activity is often broken down into two classes of motions, travel and manipulative. The manipulative component of motion refers more often than not to relatively small motions of the hand and fingers such as occur when a knob is turned or an object grasped. The travel component is the motion from one manipulation site to another. Barnes (cited 17) has reported that extending a travel motion affects neither the time required for its accomplishment nor its efficiency. However, Wehrkamp and Smith (17) have shown that increasing only the travel distance in a repetitive travel-manipulation-travel sequence can increase not only the time required for the travel motion but also that required for the unaltered manipulation task. They obtained the lowest times for the smallest travel distance investigated, 15.3-cm. Begbie (3), in an experiment involving drawing lines from one point to another found aiming errors to increase with line length, but also recorded a large jump in the relative amount of error between lengths of 24 and 32-cm. These two experiments seem to indicate a degradation of performance for sufficiently large motions.

All the work cited thus far has involved quite simple experimental tasks and the results can, at best, only hint at some of the effects that would show up in a more complex situation.

An excellent experiment by Fitts (10) has a much closer bearing on the working hypothesis as stated here. The thesis which he examined was that the channel capacity for information of the sensory-motor system used for a given class of activity is independent of the amplitude and the permissible variability of the motion. The situations which he examined were all rapid, repetitive tasks which required the operator to see what he was doing, such as transfer of pins from one set of holes to another. The experimental independent variable was the average time required to perform, say, one transfer. Using this time and the physical dimensions of the task, Fitts defined an index of performance which is proportional to the information transmission rate. The hypothesis appeared to be confirmed in outline, except that throughout all the tasks, movements of from four to eight inch amplitude were more consistently associated with good performance and the time tended to have the best values for the motions with amplitude of from four to eight inches. For larger or smaller sizes of motion, the information rate fell off, rather more abruptly for smaller than for larger amplitudes.

Fitts' experiment would seem to bear out the hypothesized relationship, though the optimum range he observed is extremely narrow compared with a person's reach of approximately 38 inches. The question that has been posed here is not decisively answered by Fitts' experiment. Vision was of considerable importance in accomplishing the task and its contribution to the resulting relation cannot be assessed. Furthermore one might surmise that the rapid repetitive nature of the task might make it more or less unique.

The Working Hypothesis and Experimental Approach

To restate, the working hypothesis adopted was that when manipulative motions of the hand and arm are within a certain range of size they are most effective, but that if they

are either larger or smaller, then the effectiveness is impaired. Furthermore the difference in effectiveness is attributed to changes in the operator's ability to make the best use of his proprioceptive senses. This hypothesis seems reasonable from ordinary observation, and is suggested by experimental findings. Moreover, such an idea is in agreement with known relations for other senses. It was thought that the region of maximum effectiveness included all but the smallest and largest motions and that within it there would be essentially no discernable differences, just as the Weber fraction for a large number of sensory modes has a broad flat region at mid-range. That such a broad optimum might not be the case, however, is indicated by the work of Fitts (10).

Concerning the design of remote manipulators, it is to be noted that the effects of extremely small or quite large ranges of motion, while interesting in themselves, are not at issue. If a transformation in the size of motion is to be useful at all it must be to one within the range of those ordinary tasks which are performed with ease. What is actually sought is the nature of the region between the extremes; whether the performance is independent of size throughout or has a peak over a relatively small portion.

It was desired to test the basic hypothesis in a context sufficiently general that conclusions could be drawn concerning manipulation. Two experimental approaches are available for assessing the effect of a change of motion size, one involves manipulation, the other does not. One could ask a subject to rearrange some aspect of his environment. This proposed change is the input and the output is an appropriate measure of how well it was performed. One could just as well rearrange a known environment and ask that the specific alteration be detected. In this case the subject's report is the output. It is maintained that for many situations, many kinds of rearrangement, these two experimental approaches, while not strictly equivalent, relate to the same intervening variables. This is true at least to the extent that a large class of manipulations involve only the same gross arm and hand movements that would be required to detect the arrangement of objects in space. In order to bring into play many of the diverse features of manipulative motions and yet keep a relatively simple situation, one not overly dependent on the equipment used, an experiment of the perception sort was devised which was intended to represent a fairly generalized kinesthetic task.

APPARATUS

In order to test the working hypothesis and with a view toward performing other experiments connected with proprioceptive feedback, a device which can be termed a remote sensor was constructed. In its essential features it is a plance pantograph which reproduces at one point the motion at another and allows for alteration of the relative sizes of the two motions in the ratios one, two, three, and four to one.

The apparatus is shown in Figures I, II, and III. One end is fitted with a knob for the operator to grasp, and will be called the operator's end. The other extremity is fitted with an electrical contact which serves as a sensor. This is the sensor end. The small platforms on which are mounted the sensor and the operator's knob slide on rounded metal glides over the mounting board which supports the entire device. To keep the inertia low without sacrificing rigidity, the linkage arms were made of 3/16 x 1/2 inch retangular aluminum stock. The sensor platform and the platform at the operator's end were made of transparent plastic and Masonite, respectively. A grip was cut in the mounting board at one side, and the entire device is light enough to be readily carried with one hand.

The extent of the sensor's motion, and consequently that of the operator's end as well, is limited by a metal ring or barrier so supported that a sheet of cardboard may be slipped into it. The cardboard is covered with aluminum foil, which is in turn covered with

paper from which a pattern can be cut exposing the foil beneath. These laminations are glued together. The cardboard sheet, or stimulus card, is held in place with a clip which makes electrical contact with the foil. The sensor is a small diameter steel rod which can slide vertically in a bushing mounted on the sensor platform. It extends down through the center of its platform to make spring loaded contact with the stimulus card inside the boundary ring. Provision is made for raising the sensor to clear the boundary so that the platform can be moved to one side for changing the stimulus.

Whenever the sensor slides over the exposed portion of the foil or touches the metal boundary, it closes a circuit. At the operator's end, at the point of the pantograph whose motion corresponds to that of the sensor, is a display consisting of a steel pin, activated by a magnet, which presses against the operator's forfinger tip whenever the circuit is closed, and remains in this position until the circuit is broken. Whenever the circuit is opened or closed, there is a clearly audible click due to the magnet armature. Power is supplied by an ordinary 1.5 volt dry battery attached to the mounting board.

To use the apparatus, the operator sits with it before him on a table as in Figure III. With his right hand he grasps the knob and places his right forefinger tip over a small hole in the cover of the display unit through which the pin protrudes. The position of this hole is clearly discernible by touch even when the display is not on . When the operator moves his hand, the path followed by his fingertip is described by the sensor over the surface of the stimulus card. The operator is blindfolded when using the device, and to provide a reference for the position of his body with respect to the apparatus he places his left hand along the edge of the mounting board, parallel with the centerline of the equipment. The device thus enables the operator to explore with his finger the plane area in front of him as if it were the region within the boundary circle. When the sensor encounters a conductive region on the cardboard sheet, it appears to the operator somewhat as a raised portion of the plane. If he tries to move his hand so that the sensor would go beyond the metal rim, the rim stops the movement and the display is activated.

Naturally, the pantograph reverses the motion, but to an observer at the other end of the board, facing the operator the motion appears just as it does to the operator except that the operator's hand motion may be either one, two, three or four times as great as that of the sensor. Provision was made for the angular displacement of the fingertip to be reflected at the sensor by an equal rotation in the proper sense. This was done with the intention of making the apparatus available for experiments involving several sensors and displays, but it was found useful for keeping the sensor platform clear of the rest of the apparatus.

It was soon found that the noise of the sensor going on or off was a display in its own right and could take the place of the projecting pin. This was so because of the extreme simplicity of the situation; any on-off signal could have been used. The tactile display and its location served to remind the subject that it was the point under his fingertip whose motion was followed by the sensor, and to emphasize the conception of the task as an actual manual exploration.

In order to record the subjects' hand motion, a sensor made from a ball point pen was used. It is shown in Figure II. Instead of a stimulus card, a sheet of paper with a hole punched at the proper location was inserted into the boundary ring with aluminum shim stock beneath it. The technique was developed toward the end of the experiment, and only a few records could be obtained.

The task required of the subjects who operated the equipment was to determine the location of an "object" within the limiting circle. At the sensor end, the object was a small circular conductive area which could have one of nine possible positions, two in each quadrant and one in the center. Figure VII shows the exact size of the spots, and their possible positions. The sensor was initially placed directly in the center of the conducting area, and the sliding platform to which the operator's knob and display were fixed was rotated so that its side was parallel to the mounting board. At the command, "Ready," the blindfolded subject grasped the control knob and positioned his forefinger over the display unit, and at the same time placed his other hand along the side of the mounting board as a reference. At the command, "Begin," the subject sought to determine which of the possible positions the spot occupied. At the end of a set time, the experimenter said, "Stop," and the subject took his hand from the knob and indicated the position he believed the spot to have by giving the corresponding number. Figure III shows the position assumed by the subject, and his manner of grasping the knob and positioning his forefinger.

The specific task was chosen for testing the working hypothesis on the basis of a number of practical requirements. It was two dimensional mainly because of the complexity of the equipment required for three dimensional work and because a one dimensional situation was considered to be insufficiently general in that it does not involve the control and feedback of direction to an extent comparable to that in most manipulations.

The use of spots of similar character but differing in position was decided upon for three reasons. The first was that this provided a task for which the strategies open to the subjects were relatively few and simple as opposed to tasks such as recognizing letters of geometrical forms in which the plan of attack would be crucial. The second reason was that having the subject try to detect the position of otherwise identical stimuli provides an opportunity for examining the way in which the constraints and the spatial relations among possible locations affect performance. The third reason was that this technique lends itself to a simple and rational criterion of the quality of performance, the information transmitted from stimulus to response. This measure, its formulation, and interpretation will be considered further on.

The circular region and circular locus of stimulus position was chosen after preliminary experiments using a square matrix. It was found that the corner locations were recognized with disproportionate ease because of their nearness to the circular boundary. The boundary shape was decided on to avoid giving the subject a known reference in the field, such as a corner, and for symmetry.

In view of the fact that perception of a region is bound to be highly dependent on its characteristics and on the restraints imposed, the task was formulated in such a way as to try to minimize peculiarities and to place the burden of recognition on the subject's kinesthetic senses and not on his peripheral abilities to formulate strategy or interpret cues provided by the boundary.

In connection with the task, some additional points concerning the apparatus should be made. Since the pantograph is, in effect, a velocity and displacement transformer, the inertia and friction forces, as felt by the operator are not the same for each ratio for a given input. It should be noted, however, that the actual "feel" in a subjective sense, while noticably different for different ratios, is not greatly so.

The moment of inertia of the apparatus about the pivot decreases with increasing ratio if the mass of the display unit is considered to be lumped with the mass of the operator's

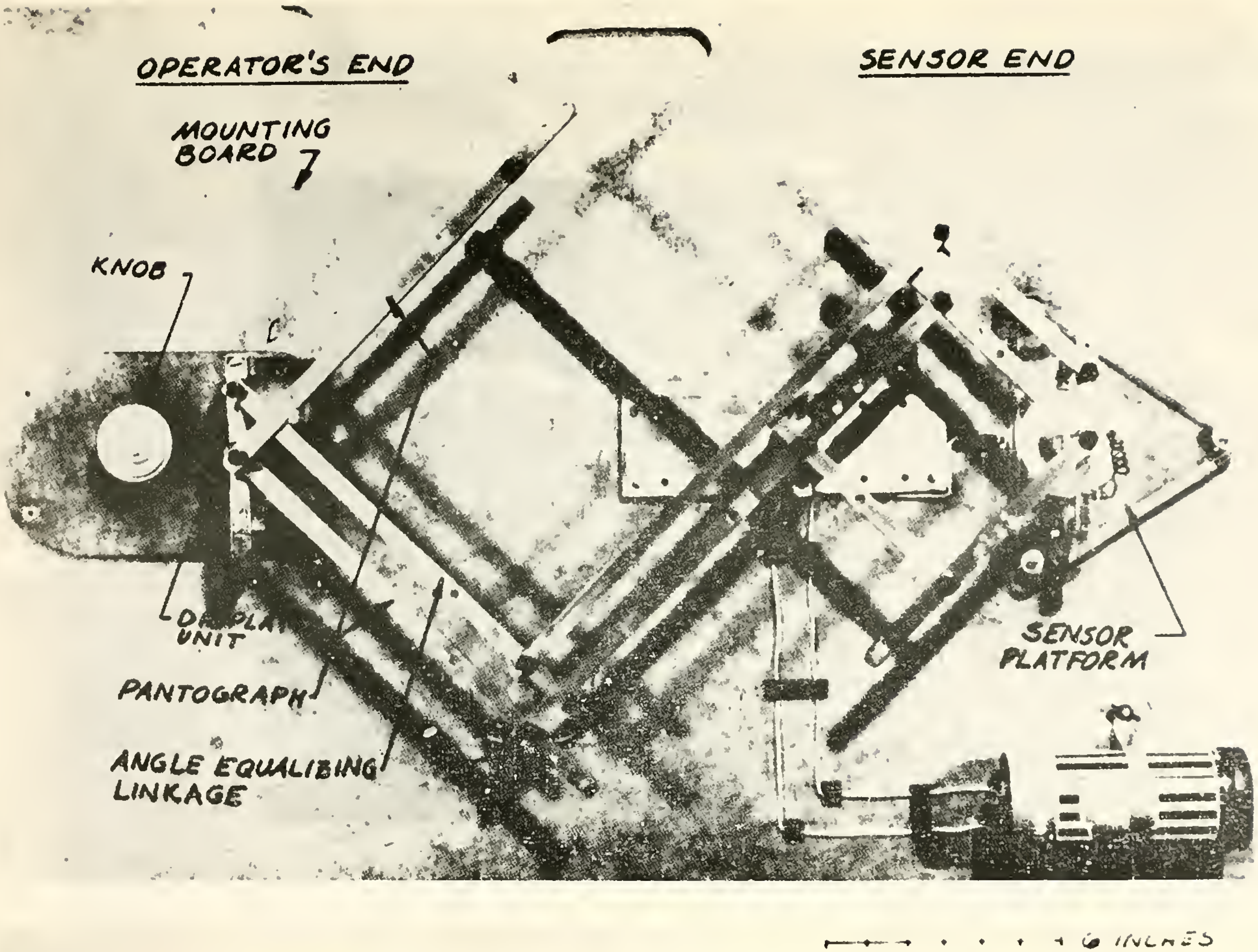


FIGURE I PLAN VIEW OF APPARATUS (Mounting board longer than shown)

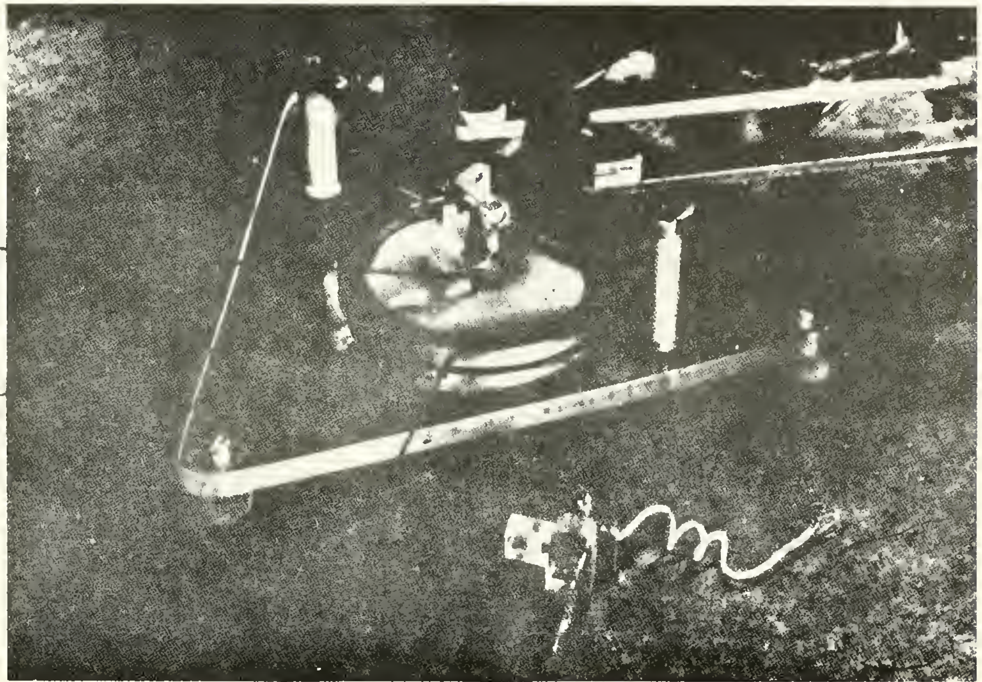


FIGURE II SENSOR END OF APPARATUS

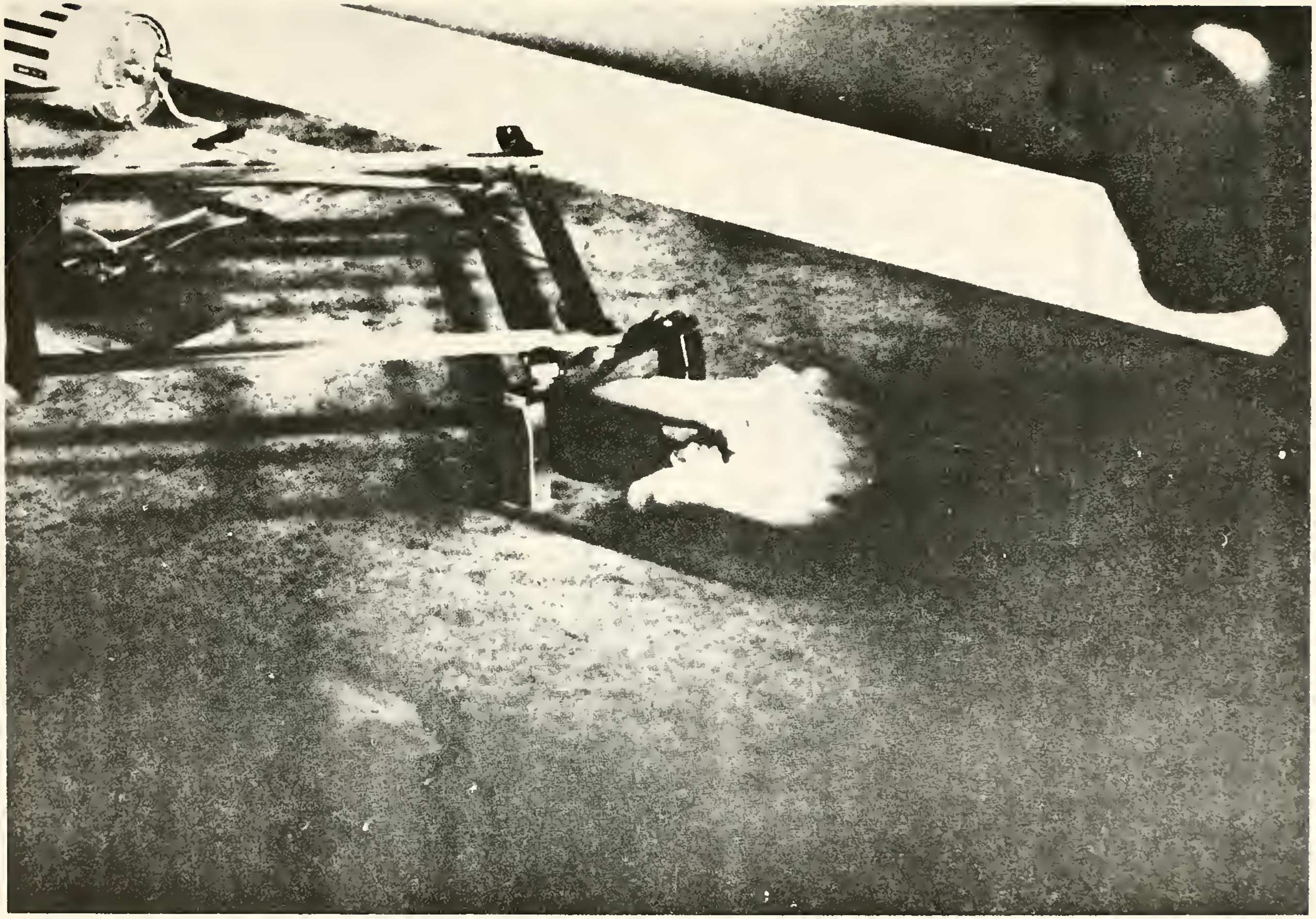


FIGURE III. SUBJECT IN PROPER POSITION TO USE APPARATUS

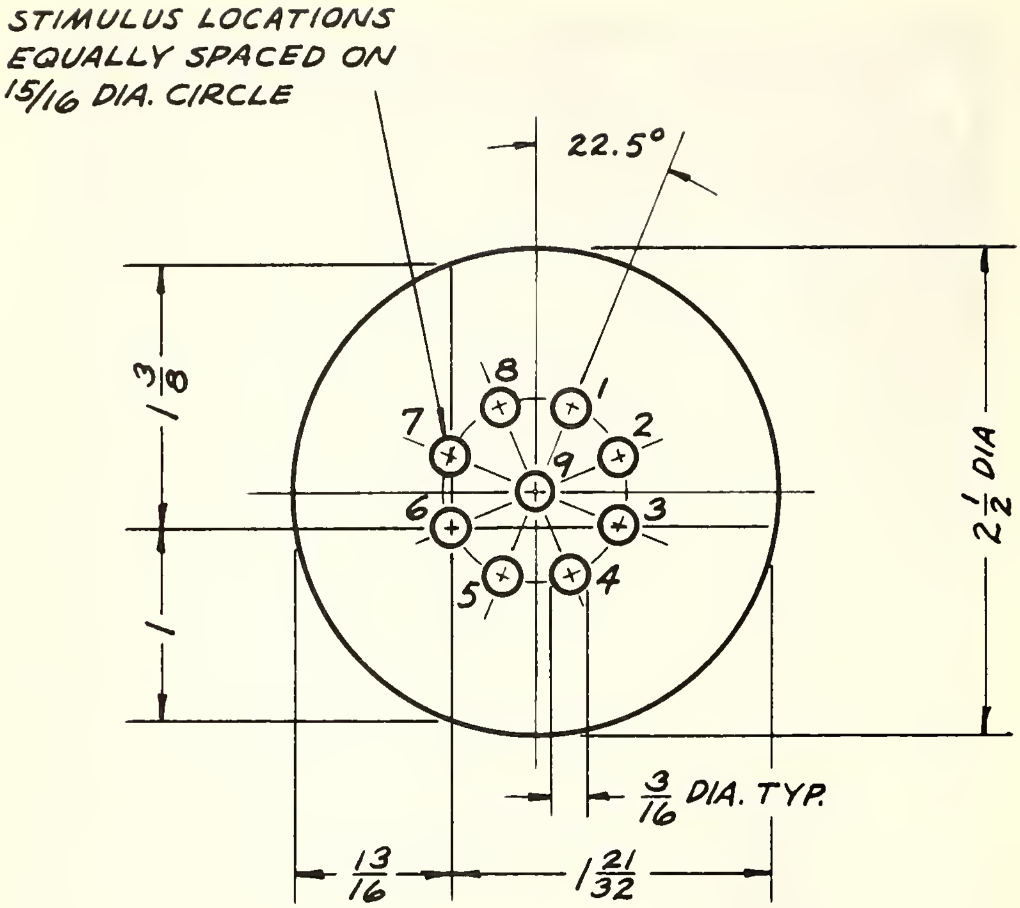


FIGURE VII. FULL SIZE PLAN OF THE EXPLORED REGION, SHOWING THE LOCATIONS AND NUMBERING OF ALL STIMULUS SPOTS

hand and arm. While the moment of inertia of the linkage alone increases, this increase is more than offset by two factors, the decrease due to the sensor's closer proximity to the central pivot, and the greater distance between the operator's hand and this pivot which creates a greater moment for a given force input. The relationship can be clearly seen by considering an analogous situation, a lever with distributed mass which has an additional mass located at the output end. If the lever is twice as heavy as the additional weight, the apparent mass of the whole unit as seen from the end of the longer arm when the ratio is four to one is less by approximately a factor of three than with the one to one ratio. On the other hand, friction forces which appear at the end with the added mass are reduced by the square of the ratio.

An alteration of the dynamic and frictional properties of the device might reasonably be expected to produce some change in the proprioceptive feedback (2), but a number of things make it evident that the extent of change in the presently considered situation does not materially affect the operator's judgments of position. For the task selected the time allowed was ample for the subject to make a large number of comparisons of the distances and exploratory motions. The problem was purposely chosen as one which would not demand high speed performance and split second timing. Thus the subjects were not called upon to use motions which would result in large accelerations and consequent large forces. It is to be noted that the friction forces, too, are not very large. The pivots in the linkage were reamed to fit precision shoulder screws, and were lubricated. The surface of the board was waxed to minimize friction from this source. As an indication of the magnitude of the static friction forces, when the device is in the 2:1 ratio the force on the knob required to initiate longitudinal movement is approximately 3.2 ounces, while in the transverse direction nearly 3.1 ounces is needed.

Weiss (18) has shown that if a lever is spring loaded, the amount of loading has essentially no effect on the subject's positioning performance when he judges the position by proprioceptive cues alone. Though this doesn't directly imply that the dynamic forces will not be important, it suggests that the position of the subject's own arm and hand is the primary factor, and that forces in general are less important. A further substantiation of this view is provided by the results of Fitts' experiment (10) described in the introduction. In his investigation of a subject's alternate tapping two targets with a hand-held stylus, two different stylus weights were used, one ounce and one pound. It was found that, while changing the size of the targets or the distance between them produced significant changes of performance level, the effect of the added weight was relatively slight. This was observed in a situation in which the motion was as rapid as accuracy would permit and the inertia forces were correspondingly large.

Goldscheider (cited in 1) showed that the apprehension of limb position is almost wholly due to receptors located in the joints, and that it is not impaired even in those persons lacking muscle sensation. Appreciation of position is quite lost, however, in those whose joint receptors do not function. The negligible effect of muscle cues on position sensing and the large part they play in detecting the forces necessary to overcome resistence also suggests that position sensing may be relatively independent of the effort required to achieve the position.

On the basis of the above arguments, it was assumed that the effects of dynamic and friction forces are negligible, in the circumstances being considered, in comparison with the more important variable, position.

ANALYSIS

The measure of performance required by the hypothesis, and the associated analysis are largely those suggested by information theory, and specifically the work of Garner and Hake (11), McGill (14), and Attneave (1). The measure of performance quality is the information transmitted from stimulus to response. The application of this measure and informational analysis to the specific situation being considered should be justified. That information theory ought not be indiscriminately applied has been well pointed out by Chronbach (16).

The experimental situation described above is, in fact, one which exhibits information flow. The experimenter is actually sending messages, all of them from a known set, to the subject who acts as a receiver whose output is the specification of one of the messages. A large number of studies have shown that the human operator, even in situations less clearly of an informational nature, can appropriately and fruitfully be considered an information channel (1, p.67 ff.)

The information measure, the transmitted information, reflects an aspect of the task which one would not want to omit, and to which a statistic like percent correct is insensitive. This aspect is the possibility that a subject may make mistakes in a definite way. The regularities of the operator's errors, such as a consistent and predictable confusion between two stimuli should be given weight since the subject's conception of the task, his postural alignment, and his personal criteria of choice, things not readily controlled, may result in different kinds of behavior among subjects and do not reflect necessarily on their capabilities. The transmitted information takes account of such regularities.

Strictly speaking, analysis of variance is not applicable to the raw data of an experiment of the present sort, since the dimensions, subjects, stimuli, responses, and ratio, are all nominal categories. (1) But multivariate information analysis is appropriate for determining the interactions, and its logical, though not mathematical, analogy with analysis of variance is complete. (1)

EXPERIMENTAL ARRANGEMENT

To test the working hypothesis, four subjects were assigned randomly to each of the four conditions. Each subject was presented with each of the nine possible stimuli a total of five times, the order of presentation being randomized either by drawing the stimulus number from a box of mixed number tokens, or from a table of random numbers. As an independent check, those two subjects who had the best performances completed all four ratios, one of them at the standard rate of fifty seconds for each presentation and the other with the reduced time of twenty seconds per presentation. The subjects were sixteen male students of the Massachusetts Institute of Technology, all but one right handed. They were paid for their participation, and generally showed a keen interest in the experiment.

Each subject was given a training period immediately before the experiment. He was first handed a typed sheet of instructions to read, explaining the equipment and describing the procedure to be followed. All the points covered in the sheet were gone over with him by the experimenter, who demonstrated the equipment, the manner in which the subject should seat himself, and how he should hold the knob and position his finger on the apparatus. The experimenter then made sure that the subject understood the numbering of the stimuli.

The experimenter remarked that the subject could use any way he wished to try to determine which stimulus was presented, but that the following points should be recognized.

1) The two distances, from the spot to the far boundary and from the spot to the near boundary could be used to determine the position in the longitudinal direction; and similarly the distances in the transverse direction could be used to locate the stimulus in that dimension.

2) If he wished, the subject could locate any point on the restraining circle by scanning along the boundary and estimating the location from the change in curvature. This technique was also demonstrated.

3) Until the location of the spot is pretty well decided, it is best, when moving away from it toward the boundary, to do so in such a way as to keep account of the motion so that the spot can be returned to; for if the stimulus is lost, time would be wasted in hunting for it.

4) If the stimulus spot could not be located, scanning for it should be systematic; but scanning by moving the finger tip in a circle should be avoided since it was found to be relatively ineffective.

The purpose of bringing out these points was to try to prevent aimless wandering over the region and to indicate useful techniques that might otherwise be overlooked. It was also the intention to prevent bizarre strategies from being used. To a large degree this was achieved, but a certain amount of apparently irrational moving about was shown by all but one of the subjects.

It may be argued that these instructions could introduce a systematic bias into the results. This is conceivable since it is well known that the constraints in a task are not wholly those of the physical situation, but include the mental bias of the person engaged. The other alternative would be to allow sufficient practice for the subject to discover and adopt a strategy of his own. However irrational it appeared it might produce the best results for him.

Concerning the last two points, preliminary experiment showed that they are simply facts which could not be ignored in any strategy. With regard to the first two points, it is the writer's opinion that the situation is not so rich in strategic possibilities that any potentially successful method was precluded. Moreover, the reference chosen, the side of the mounting board was a much stronger influence toward using the longitudinal and transverse motions. A few trials makes it quite apparent that these are the easiest to maintain Movements along the boundary were tried by all and adopted as a useful method to varying degrees. All the subjects tried movements of various kinds and the total practice time of nearly twenty minutes allowed considerable experimentation.

After the demonstration the subject was permitted to handle the equipment and to see how large a motion his hand made when moving around the limiting circle. He was then blindfolded and, to familiarize him with the stimuli and the manner of working the equipment, he was presented once with each of the stimuli, in essentially random order, and was given two minutes to explore each. As soon as he had decided which position was represented, he told the experimenter who indicated whether the answer was correct. If the two minutes elapsed without the correct answer being given, the experimenter gave the answer and permitted the subject time to assure himself that it was so.

The experiment proper began after the nine training attempts. Each stimulus was then presented five times in random order and the subject was instructed to spend the entire allotted time on each, making sure of his answer if he had already decided before the time was up. He was not informed of the correctness of his estimates until after the experi-

mental session, and he was instructed to make his best guess in the event of indecision. Between presentations the subject took his hand from the knob. The forty-five presentations required somewhat less than an hour to complete. When twenty-five had been made, the subject was given the opportunity to stand and stretch or get a drink of water. The opportunity was usually refused.

The same procedure was followed for all the subjects except for those two who performed at all ratios. For them, on trials after the first, the introductory instructions were omitted. For the subject who performed at all ratios with a twenty-second time limit, the training time was reduced from two minutes per presentation to one.

At the beginning it was believed that there would be a very large amount of learning involved in the experimental situation and that major differences between subjects due to different learning behavior could be expected if each subject were to complete the entire set of four ratios. It was further thought that since the task was so straight forward and simple in conception that the differences in ability between subjects would not be very great. In such circumstances, the application of a latin square design using a number of subjects, each subject undergoing each of the conditions, is an improper procedure, since successive trials are not independent. For these reasons it was decided to use each subject only once under the controlled training conditions, thus using a different set of subjects for each ratio. In view of the results, as will be later shown, this may not have been a wise choice. The differences in ability and assurance with which the individuals handled the apparatus were quite large, indeed so large as to outweigh in all probability any improvement in performance they might have shown as a result of greater familiarity with the situation after several trials.

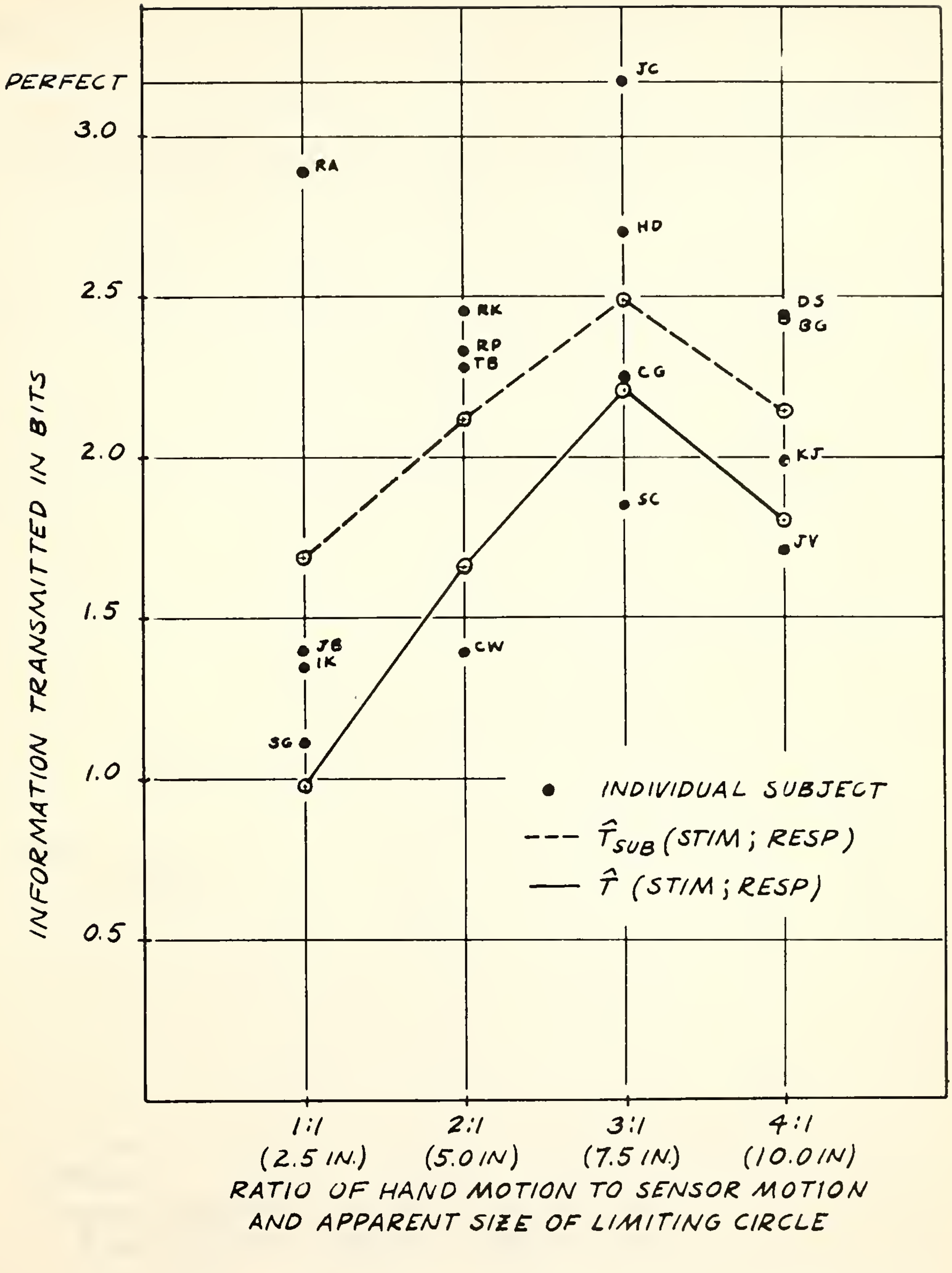
It was mainly for reasons related to this difference in ability that two subjects were given the entire set of ratios. They were chosen because of their superior performance on the first trial and the assumption was made that because of the good performance they could be considered as "practiced" and that there would be little subsequent learning. The form of their information transmitted vs. ratio curves was intended as a check on the general relationship obtained.

PRESENTATION OF RESULTS

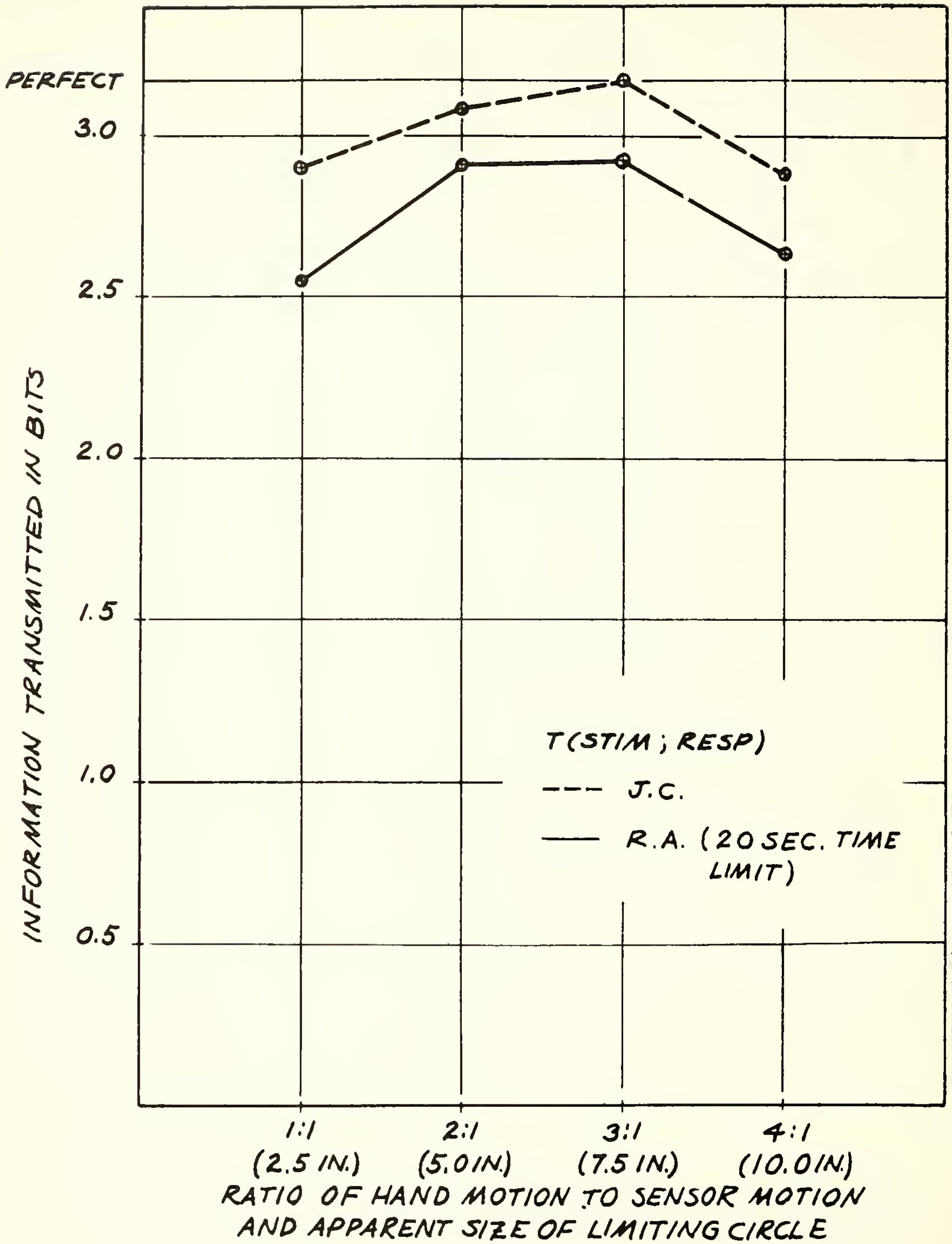
The results of the experiment are summarized in the form of graphs on the following pages. Graph I shows information transmitted plotted against ratio for the main series of experiments using four subjects for each ratio and one trial for each subject. Graph II presents the results for the two subjects who performed at all ratios. Finally Graph III shows the percentage of errors at each stimulus position by ratio, and Graph IV the error percentages calculated by summing errors over all ratios. The two latter graphs include the errors made by the subjects completing all ratios. Some typical traces showing the sensor path were obtained for two of the subjects, and they are presented in Figures IV and V.

The raw data is included in the Appendix in the form of contingency tables. There is one table for each trial. In addition there are several tables formed by pooling data from individual trials. These represent aspects of three or four dimensional contingency tables, and were prepared primarily for computational purposes. Specifically there is a pooled table for each ratio, one formed from these four, and one for each of the two subjects who completed all ratios. Having the data in this form is also useful for visualizing the results and for qualitative comparison.

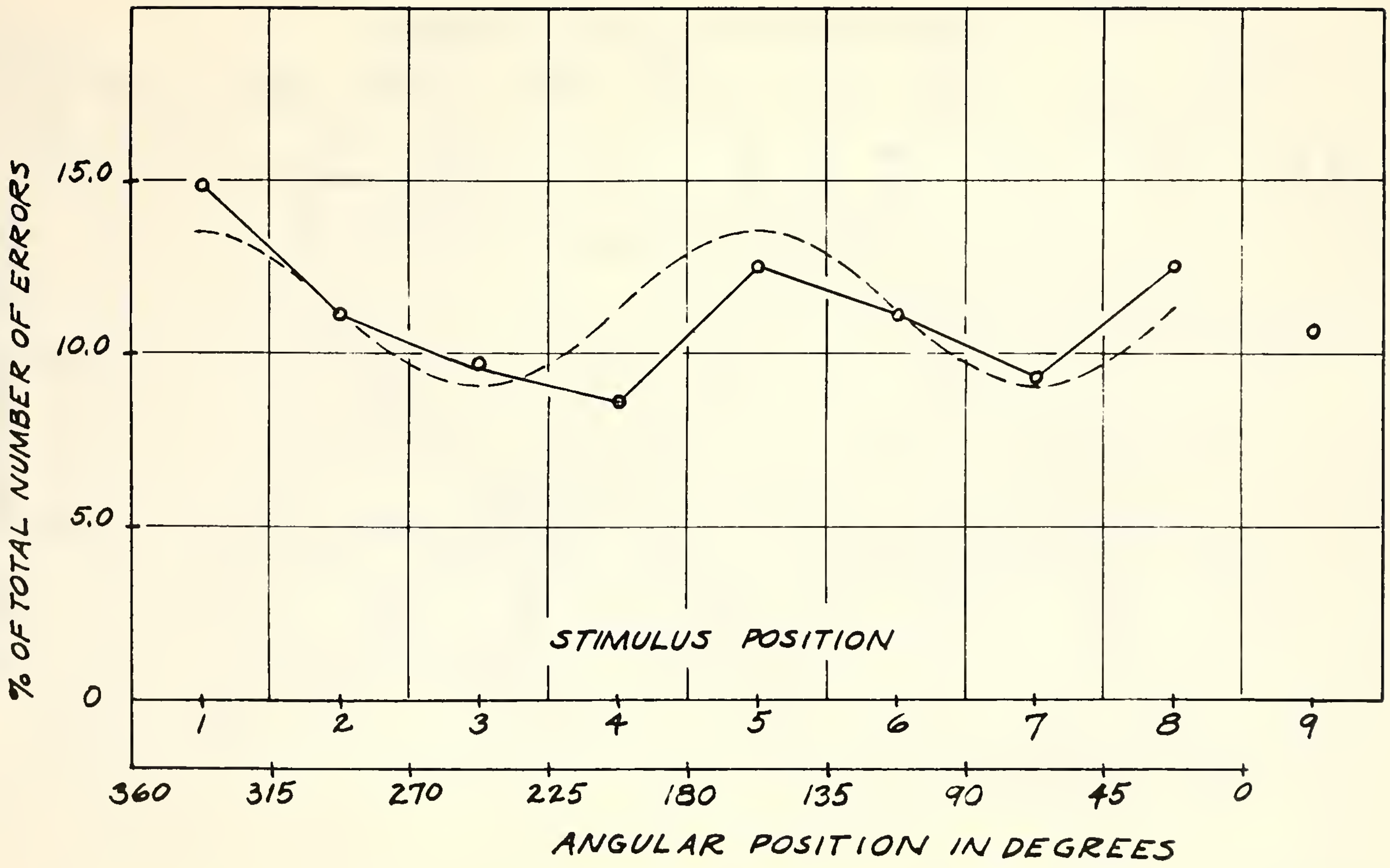
An assessment of the statistical significance of the information measures was made on the basis of the fact that the asymptotic distribution of measures of transmitted information is chi-square. Furthermore, the experiment was so designed that there would be no



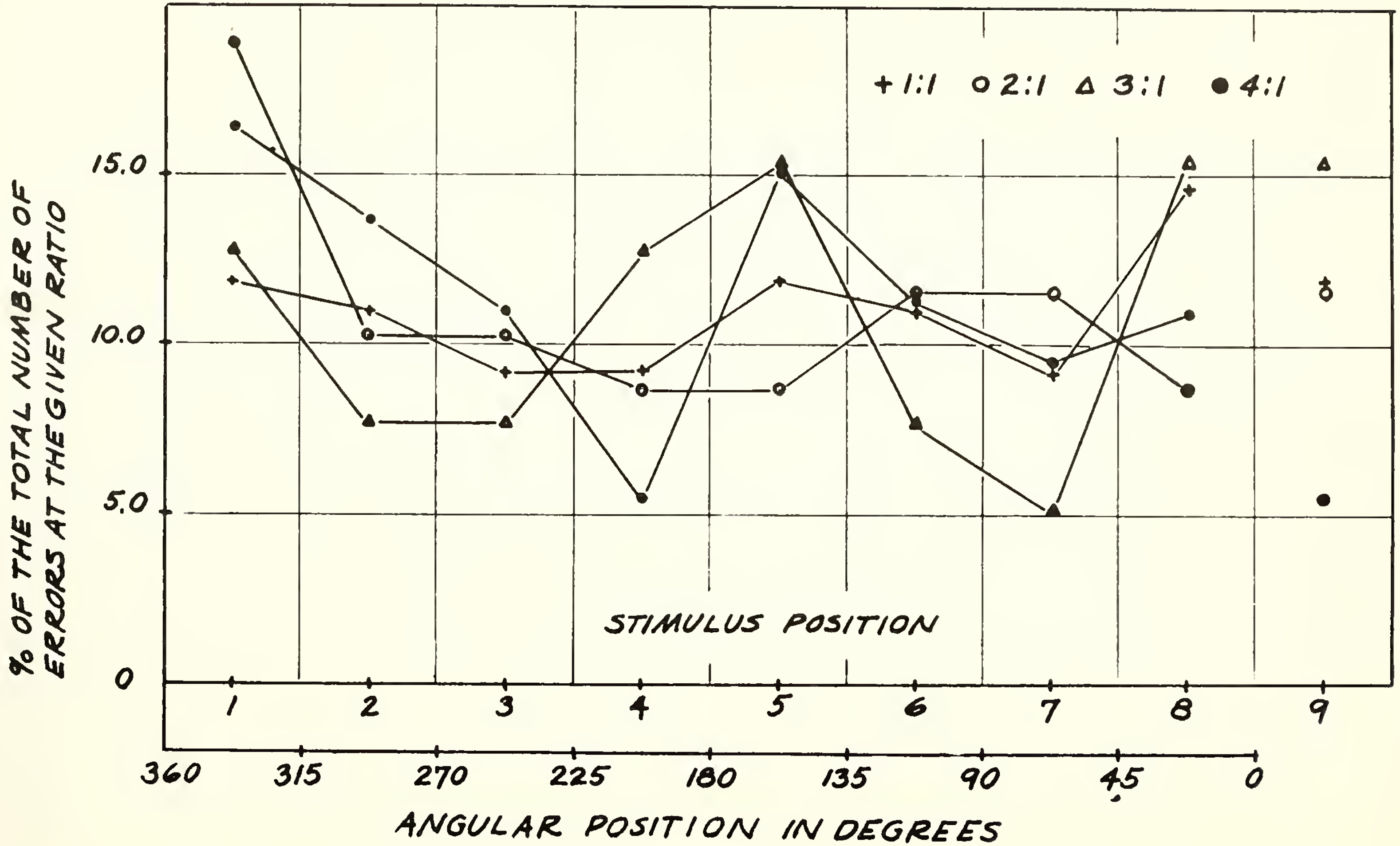
GRAPH I. INFORMATION TRANSMITTED FROM STIMULUS TO RESPONSE AS A FUNCTION OF RATIO BETWEEN SUBJECT'S HAND MOTION AND THE SENSOR MOTION



GRAPH II. INFORMATION TRANSMITTED FROM STIMULUS TO RESPONSE AS A FUNCTION OF RATIO BETWEEN SUBJECT'S HAND MOTION AND THE SENSOR MOTION FOR SUBJECTS R.A. & J.C.



GRAPH III. PERCENTAGE OF ALL ERRORS AS A FUNCTION OF STIMULUS POSITION. THE SINUSOIDAL CURVE IS EXPLAINED IN THE TEXT.



GRAPH IV. ERROR PERCENTAGES AS A FUNCTION OF STIMULUS POSITION FOR THE FOUR RATIOS OF HAND TO SENSOR MOTION

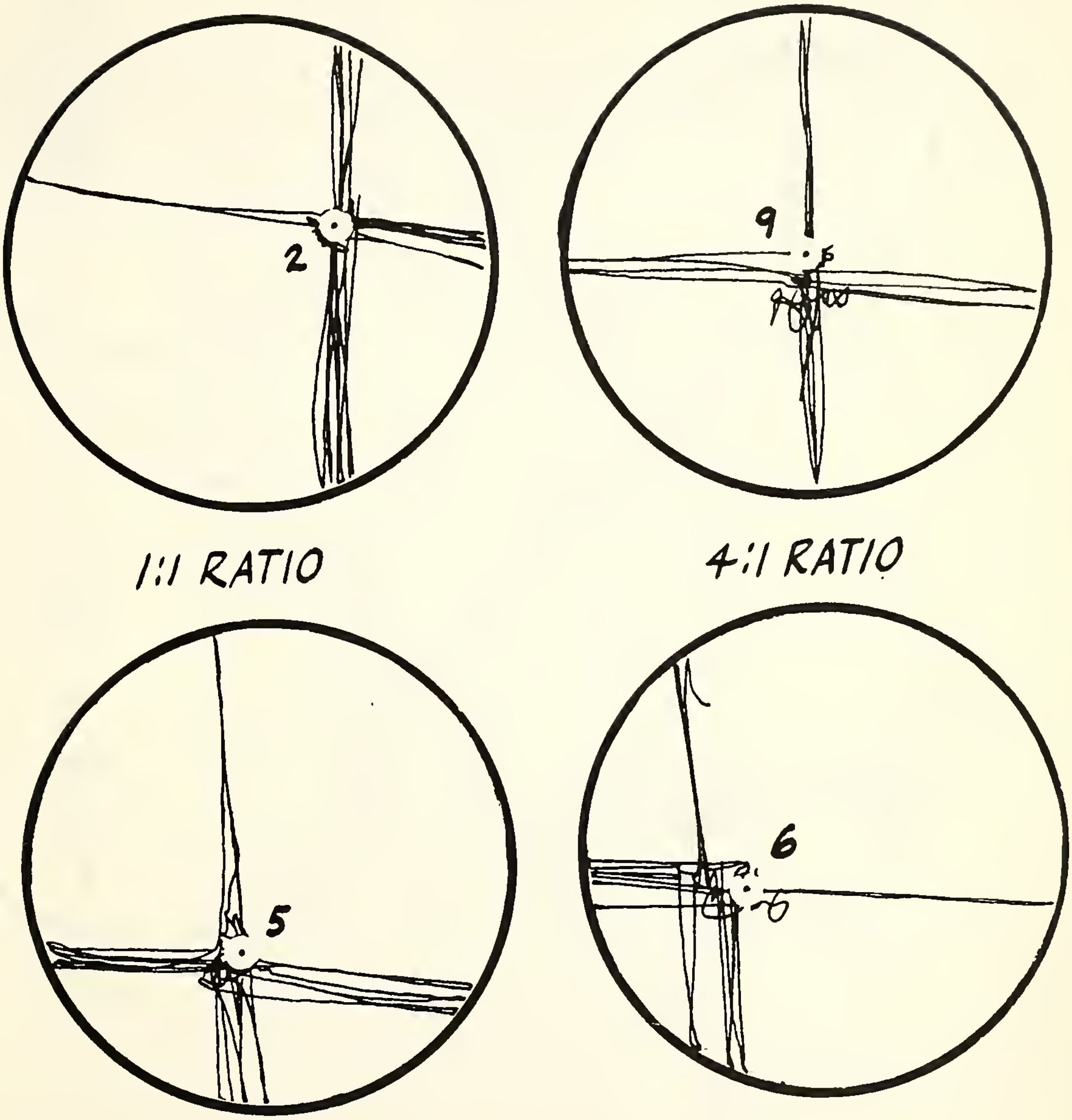


FIGURE IV. TYPICAL SENSOR PATHS, SUBJECT R.A.
Re-inked over ball pen trace. All stimuli were correctly identified.

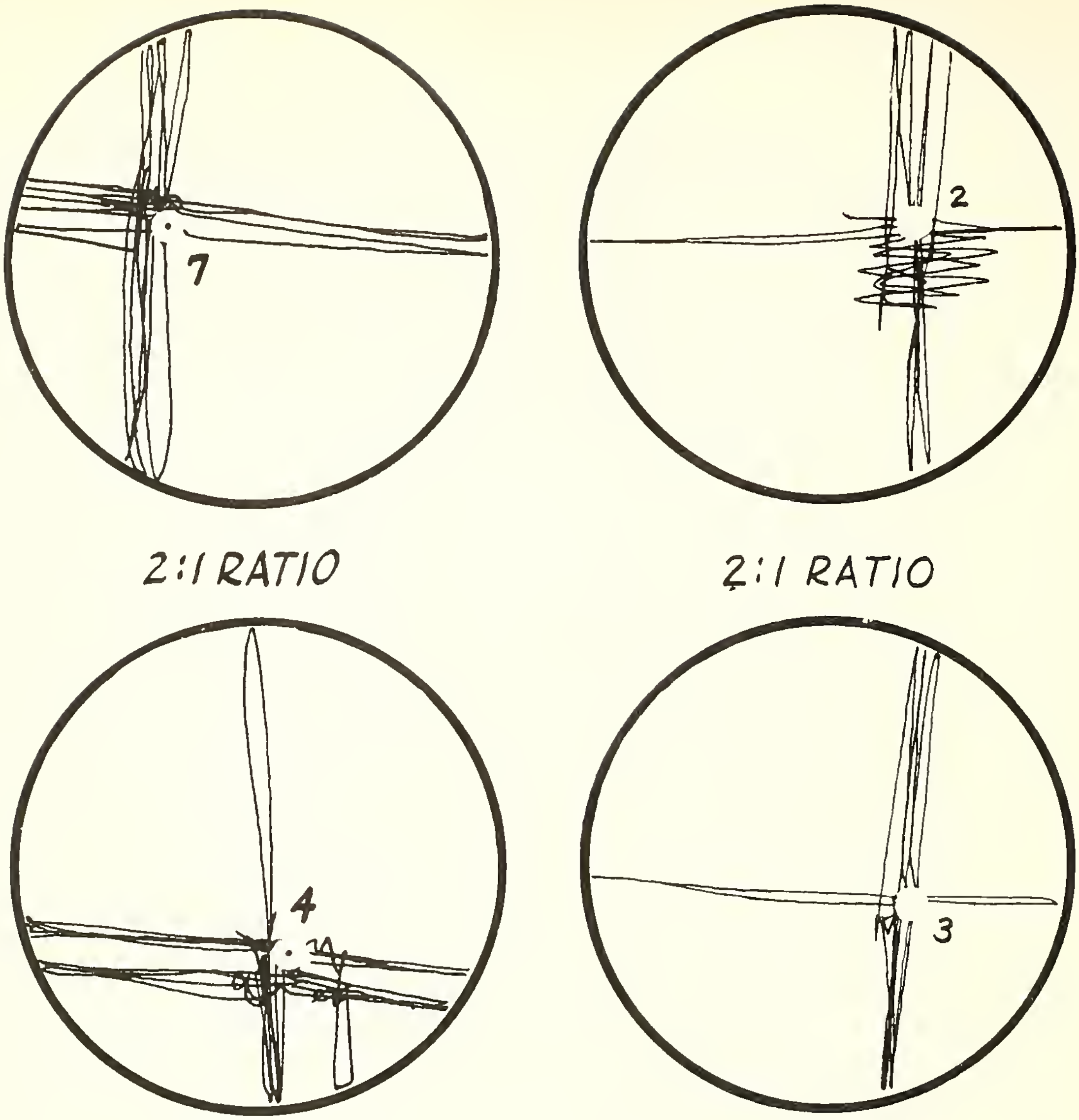


FIGURE V. TYPICAL SENSOR PATHS
SUBJECTS R.A. (left) AND J.C. (right)
Re-inked over ballpen trace. All stimuli were correctly identified.

TABLE	TRANSMISSION	VALUE IN BITS	DEGREES OF FREEDOM	APPROX. TO χ^2	5% LEVEL OR BETTER SIGNIF.
ALL RATIOS, STIM x RESP x SUBJ x RATIO	$\hat{A}$ (STIM; RESP; RATIO)	0.232	192	1.97	YES
	$\hat{A}$ (STIM; RESP; SUBJ)	0.677	192	17.19	YES
1:1 RATIO, STIM x RESP x SUBJ.	$\hat{T}$ (STIM; RESP)	0.985	64	10.9	YES
	$\hat{T}$ (SUBJ; RESP)	0.127	24	31.58*	
	$\hat{A}$ (STIM; RESP; SUBJ)	0.702	192		
	$\hat{T}_{SUBJ}$ (STIM; RESP)	1.686	256		
	$\hat{T}_{STIM}$ (SUBJ; RESP)	0.828	216		
2:1 RATIO, STIM x RESP x SUBJ	$\hat{T}$ (STIM; RESP)	1.664	64	17.5	YES
	$\hat{T}$ (SUBJ; RESP)	0.071	24	17.60*	
	$\hat{A}$ (STIM; RESP; SUBJ)	0.452	192		
	$\hat{T}_{SUBJ}$ (STIM; RESP)	2.116	256		
	$\hat{T}_{STIM}$ (SUBJ; RESP)	0.523	216		
3:1 RATIO, STIM x RESP x SUBJ	$\hat{T}$ (STIM; RESP)	2.213	64	21.0	YES
	$\hat{T}$ (SUBJ; RESP	0.062	24	15.56*	
	$\hat{A}$ (STIM; RESP; SUBJ)	0.279	192		
	$\hat{T}_{SUBJ}$ (STIM; RESP)	2.492	256		
	T_{STIM} (SUBJ; RESP)	0.341	216		
4:1 RATIO, STIM x RESP x SUBJ	$\hat{T}$ (STIM; RESP)	1.796	64	18.5	YES
	$\hat{T}$ (SUBJ; RESP)	0.083	24	20.65*	
	$\hat{A}$ (STIM; RESP; SUBJ)	0.346	192		
	$\hat{T}_{SUBJ}$ (STIM; RESP)	2.142	256		
	$\hat{T}_{STIM}$ (SUBJ; RESP)	0.429	216		
SUBJ J.C., STIM x RESP x RATIO	$\hat{T}$ (STIM; RESP)	2.924	64	26.9	YES
	$\hat{A}$ (STIM; RESP; RATIO)	0.085	192		
	$\hat{T}_{RATIO}$ (STIM; RESP)	3.009	256		
SUBJ R.A., STIM x RESP x RATIO	$\hat{T}$ (STIM; RESP)	2.628	64	24.9	YES
	$\hat{A}$ (STIM; RESP; RATIO)	0.123	192		
	$\hat{T}_{RATIO}$ (STIM; RESP)	2.751	256		
INDIVIDUAL, STIM x RESP	$\hat{T}$ (STIM; RESP)	SEE APPENDIX B	64		

* VALUE FOR χ^2, NOT APPROXIMATION

FIGURE VI. TABULATION OF VALUES OF INFORMATION MEASURES. SIGNIFICANCE WAS NOT TESTED WHEN DEGREES OF FREEDOM GREATER THAN NUMBER OF OBSERVATIONS.

information transmitted from one input, subjects, stimuli, or ratio, to another. In this special case the interaction terms cannot be negative and can also be tested by chi-square.

It should be noted that from a statistical point of view there are two opposing tendencies. In the first place, relatively small samples were dictated by the length of time required to make the observations. Small samples, of course, tend to reduce the confidence one can place in the results. On the other hand, a glance at the pooled tables in the Appendix shows that many of the possible entries were not filled; the table for all ratios shows that 13 of the conceivable confusions as to which stimulus was presented were not made even once. As a result, the number of degrees of freedom of the chi-square variate that are calculated will be an overestimate of the actual number by an uncertain amount and significance will thereby be underestimated. Miller (16) has suggested that the degrees of freedom be corrected by subtracting one for each table position assumed to be impossible In view of the somewhat small samples, however, it was decided to make no corrections in the degrees of freedom, and to use the calculated number. Because of the uncertainty in the degrees of freedom no estimate of bias in the measures was made. Bias corrections can be computed when the number of degrees of freedom is unambiguous (16, pp. 95-113). In general, the problem of sampling in connection with information measures is not fully understood (1, p.66), but it is believed that where significance tests are applied here, the use of the calculated number of degrees of freedom assures that the estimates are sufficiently conservative. Whenever the number of degrees of freedom exceeded the number of observations on which a measure was based, no tests were made.

The measures of information and interaction are tabulated in Figure VI along with their values and significance estimates. The 5% level was assumed, and when the number of degrees of freedom was more than thirty, the approximation to chi-square, was used.

NOTES ON THE SUBJECTS' STRATEGY AND TECHNIQUE

The subjects' performances differed in several ways. Aside from the differences in the information transmitted from stimulus to response, $\hat{T}$(stim;resp), the performance criterion that was adopted, there were differences in the strategy used and in what might be called style. In general, the strategies, the techniques relied on to judge the location of stimuli, were much the same except for matters of emphasis. Style, on the other hand, the general characteristics of the execution of the motions involved, differed markedly. Some subjects used quick, confident motions; others' movements were slow and cautious; and still others oscillated between the extremes. Moreover, no universal relation between accuracy and style could be observed. Slow careful movements or quick sloppy ones could be either effective or not depending on the subject.

In the matter of strategy, all the subjects relied most heavily on longitudinal and transverse motions across the limiting circle and through the stimulus spot for making their judgments. The only other commonly used technique was scanning the boundary circle to try to find an absolute location. This was usually resorted to after the other method had been used, and to try to aid the subject in a decision between two possible locations. For example, a subject would try to locate the rightmost point on the circle to decide whether the stimulus were 2 or 3. Having located the point, he would move to the left along the transverse diameter to the approximate region of the locus of the stimulus spots and search away from himself if he thought the stimulus were number 2, or toward himself if he thought it were 3. The points on the circle thus located were almost invariable the four cardinal points. In the writer's judgment, since he could observe the sensor motion through the transparent sensor platform, these points were located quickly and with surprising accuracy. All the subjects tried this technique during practice and accepted it to varying degrees, but, on the whole, it was sparingly used. However, it may be signi-

ficant that the two who had the best performance, J.C. and R.A., used the method the least; J.C. only once, and R.A. not more than five or six times.

In making his motions from the stimulus spot to the boundary and back, none of the subjects was able always to return precisely to the spot. This tendency to lose the spot was noticable at the 1:1 ratio for which its apparent size was least. The methods for finding the stimulus once it was lost varied considerably. They could be classified mainly as either systematic or not. As one might suppose, systematic scanning was generally rewarded with better performance, but frequently, as was the case with R.A., the rapidity of the scanning motion seemed to make up for lack of precision. Several subjects, notably C.G. tended to scan using a circular motion inspite of the experimenter's initial caution against it. The uniform result was that the subject went round and round the spot a large number of times before finding it again. Seemingly ineffectual behavior was observed occasionally, such as stopping altogether, or moving over the limiting circle when the spot could not be found.

Unfortunately, only a few records of the path of motion were obtained, and these only for R.A. and J.C. whose strategies were essentially the same, and whose performance was the best. The general characteristics of their movement patterns can be seen in Figures IV and V. All the traces for R.A. were made using a 20 second exploration time, and those for J.C. with a 50 second period. The larger number of lines for R.A. who used the shorter time indicate how much more rapid were his movements.

In view of the variations among the subjects in style and strategy, it is probably a valid criticism of the experiment that these individual characteristics were not sufficiently controlled. Such control is naturally difficult to accomplish without making the situation totally unrealistic. In the writer's view, at least, no systematic bias was introduced by the procedures used.

DISCUSSION OF THE EFFECT OF RATIO ON PERFORMANCE

The relationship of the ratio between hand and sensor motion and performance as measured by information transmitted is presented in graph I. The unconnected points represent information transmitted from stimulus to response, $\hat{T}$(stim; resp), for a particular subject. Two sets of points are connected. The one with the broken line represents the average of the individual points for each ratio, $\hat{T}$ subj(stim;resp). The lower curve is that for the measure of performance, $\hat{T}$(stim;resp), which is calculated from the contingency table of stimuli X responses X subjects for each ratio. The difference between the two curves is the value of the interaction term $\hat{A}$(stim;resp;subj) which indicates the effect of the subjects on the transmission from stimulus to response. As can be seen from the table of Figure VI, the values of $\hat{T}$(stim; resp) for each ratio are statistically significant. This is to be expected since the task was designed to produce information transmission. The other values were not tested because the number of degrees of freedom associated with them exceeded the number of observations on which they were based.

It is clear that there was a marked difference in the amount of information transmitted depending on the ratio used. The interaction term, $\hat{A}$(stim;resp;ratio) is the measure of the effect of ratio on transmission between stimuli and responses. It has been computed from the four dimensional contingency table, stimuli X responses X subject X ratio, representing all the data summarized in Graph I. This interaction, with a value of 0.232 bits is found to be significant at the 5% level. In other words, the ratio had a significant effect on the way responses were made to the stimuli, and hence on the transmitted information, $\hat{T}$(stim; resp).

The general character of the functional relation between motion size and performance is that predicted by the working hypothesis; there is a central maximum with relatively impaired performance for both larger and smaller motions. But the sharpness of the peak the definite superiority of the 3:1 ratio, was not anticipated, nor was the marked inferiority of 1:1. The hypothesis of a broad flat maximum must consequently be rejected. If the range of the maximum is, arbitrarily, taken to be from halfway between 2:1 and 3:1 to halfway between 3:1 and 4:1, the difference in the largest motion size over this range is only 2.5 inches, which is certainly less than 10% of the effective reach of the subjects.

To obtain somewhat independent confirmation of the relation between performance and ratio, the two subjects, R.A. and J.C. were tested at all ratios and the results are shown in Graph II. These subjects were atypical in their skill and assurance with the apparatus, but it was believed important to choose skilled subjects to minimize learning effects since only two were used, each with a different exploration time.

J.C. performed at all four ratios using the same 50 second time as did the subjects in the main series of experiments. His first trial, at 3:1, for which he had a perfect score, is included in the data of both Graphs I and II. R.A., too, used all ratios, but was allowed only 20 seconds to investigate the stimulus. The results for the two subjects follow the same pattern observed in the first part of the experiment, though at a much higher level of performance and with a much less pronounced difference among ratios.

It is possible that the nearly perfect transmission masked, somewhat, a tendency for a sharper maximum at the 3:1 ratio. Had the possible value of $\hat{T}$(stim; resp) been raised by there being more stimulus categories, or had the task been made harder by, for example, reducing the size of the stimulus spots, the peak range might have been more clearly defined. This is supposition, however.

The fact that R.A. performed so well even when he was allowed less than half the usual time is interesting. It indicates that the differences in skill between the subjects are less clearly reflected by their information transmitted values than they would be by a measure of their maximum rate of transmission. This would be expected on a priori grounds. Furthermore, the results suggest that the 50 seconds permitted the other subjects was ample, and that the original assumption that the dynamics of the apparatus were not of crucial importance was probably correct.

Graph I also shows that there was a rather wide range of performance among the subjects, especially at the smallest ratio. The interaction term $\hat{A}$(stim;resp;subj) is a measure of the effect of the subjects on the transmission from stimulus to response. The value of this term for the contingency tables representing each ratio is the difference between the points on the two curves of the graph, and the values are tabulated in Figure VI. The A terms are sensitive both to the spread in individual transmission values and also to the extent of internal inconsistency in the subjects' responses. The values of $\hat{A}$(stim;resp;subj) are very nearly inversely proportional to the value of $\hat{T}$(stim;resp) associated with the same ratio. But the scatter of individual results is not related in this way to the information transmitted, being larger for the 3:1 ratio than for either 2:1 or 4:1. This indicates that there is a fairly strong tendency for greater consistency of response to be associated with those motion sizes showing better performance.

As an example of the kind of inconsistency referred to, a subject could, in theory, incorrectly report every stimulus but still show perfect transmission providing his misjudgments were always the same and that no two stimuli were both mistaken for the same one. This could conceivably be true, say, for four subjects at one ratio. The average value of their transmitted information, $\hat{T}_{subj}$(stim;resp) would then be the maximum. But unless

all made precisely the same confusions, the value of $\hat{T}$(stim; resp) calculated from the three dimensional table would be much less. Since

$$\hat{A}(\text{Stim;resp;subj}) = \hat{T}_{subj}(\text{stim;resp}) - \hat{T}(\text{stim;resp})$$

the interaction due to the lack of agreement among subjects would be large. Even a glance at the data in the Appendix shows, in a qualitative way, that there was more inconsistency among the subjects for ratios giving a smaller value of $\hat{T}$(stim;resp).

The way in which $\hat{A}$(stim;resp;subj) varies substantiates, somewhat, the functional relationship between performance, as measured by $\hat{T}$(stim;resp), and ratio, shown on Graph I. If a change in the size of motions required really makes the task easier, not just different in some other way, then one would normally expect the subjects to be in better agreement as to the nature of the configuration being explored. The more skilled would still make fewer errors than those less skilled, but the kind of error distributions would be more the same, giving greater internal consistency to the data.

The value of $\hat{A}$(stim;resp;subj) has been computed for the four dimensional table involving all the ratios. It measures the effect of subjects on the transmission from stimulus to response just as $\hat{A}$(stim;resp;ratio) measured the effect of the motion size. The interaction term for subjects was found to be 0.677 and is significant well beyond the 5% level. This is quite large compared with the value of 0.232 found for the interaction term for ratio. This means that one would be in a better position to predict responses if one knew how the particular subjects behaved than if one knew only which ratio was being used.

In general, the spread of the individual values, the small samples used, and the significant interaction among subjects, stimuli and responses suggest that one should probably not interpret the exact form of the relation between performance, as measured by $\hat{T}$(stim; resp), and ratio as being entirely representative of the population sampled. On the other hand, several factors also indicate that the general nature of the relationship is a fact for the given task. The significant interaction among motion size, stimuli, and responses; the way in which consistency among subjects improved just as did $\hat{T}$(stim;resp); and the agreement with the results from the two subjects who performed at all ratios are all clear evidence.

It has been demonstrated that in certain kinds of manual task, for which kinesthetic feedback of position is important, it may be possible to achieve optimum performance by simply magnifying the task situation. It has also been shown that this may be true even for a task which would not ordinarily be thought too small to perform effectively. A particular magnification ratio which gives optimum performance has been found for the present experiment, but it is quite clear that not ratio but motion size is the important variable. Had all the dimensions of the stimulus card been twice what they were, the optimum ratio would have been 1.5:1 instead of 3:1. The question then arises whether one can unequivocally associate with the best performance a particular size of motion, a size which one should perhaps try to duplicate at the master controls of a remote manipulator for tasks of a similar sort. The answer, unfortunately, is no; the reason being that the way subjects used the information in the stimulus field is not precisely known.

Reference to Figure VII will show that there are a number of motion sizes which can be associated with the task. To find the hand motions involved, the dimensions on the figure are to be multiplied by the ratio used, of course. Which of these dimensions, or what function of them, to associate with the task depends on the way the subjects made use of them to form their judgments of stimulus location. There are at least three possibilities:

1) The subjects judged location primarily on the basis of the ratio in which the stimulus spot divided the distance between one side of the limiting circle and the other. This would imply that the chordal distance across the circle, or as an approximation, the

diameter of the circle, is the important distance. Since the stimulus spot always divides the distance in the same way, regardless of the relation between sensor and hand motion, the best performance would be found when the distance across the limiting circle allowed the best determination of the ratio.

2) The subjects' estimate of the stimulus positions was based on the difference between the distances from the spot to one side of the circle and to the other. The implication is that the extent of this difference is the important length. This is ambiguous, however, for there are two differences associated with each of the stimulus locations, except number nine, depending on whether the direction taken is longitudinal or transverse. One might, alternatively, specify the range of the differences as the significant dimension.

3) The estimate of location was based on a judgment of the absolute distance from the stimulus spot to the bounding circle. Insofar as the subjects used transverse and longitudinal motions, there are four distances associated with a stimulus location, and again the range would be an appropriate measure.

The table below presents all these distances for easy comparison.

Basis for Judgment	Ratio of Hand to Sensor Motion 1:1	2:1	3:1	4:1
1) Ratio	$2\frac{1}{2}$	5	$7\frac{1}{2}$	10
2) Difference	3/8 - 1 $\frac{1}{4}$	3/4 - 2 $\frac{1}{4}$	1 1/8 - 3 3/4	1 $\frac{1}{2}$ - 5
3) Absolute Length	13/16 - 1 21/32	1 5/8 - 3 5/16	2 7/16 - 4 31/32	3 $\frac{1}{4}$ -6 5/8

Table of motion sizes or ranges of size associated with different ways of judging stimulus location. All dimensions are in inches.

It may be true that judgments were based on some combination of the methods described above. Certainly other cues were used, such as the location of points on the circle. The reports of the subjects are of little help. In their view, they judged how "different" the particular distances were. But the variable which determines the difference, ratio, linear difference, or some function of absolute length, cannot be found by introspection.

As a tentative hypothesis, the writer would suggest that the extent of the motion from one side of the limiting circle through the stimulus spot to the other side is the principal determinant of performance quality for the task used. When the ratio is changed, it is the change in the extent of this motion that is most striking. All the subjects made use of this kind of movement, though sometimes they tended to pause slightly at the stimulus spot. Moreover, such a hypothesis gives a result for this experiment that is not inconsistent with that obtained by Fitts (10), discussed in the Introduction, which indicated superior performance for motions of from 4 to 8 inches in extent when the task involved rapid repetitive movements from side to side. Taking the apparent diameter of the limiting circle as the significant dimension in the present experiment, the motion associated with the best performance is 7.5 inches. The diameter, at the 2:1 ratio, of 5 inches is still in the range determined by Fitts even though performance was about the same for it as for the 4:1 ratio which had a diameter of 10 inches. Thus the agreement is not perfect, but such would be unlikely since the two experiments were of quite different character.

It is a rather serious weakness of the experiment that the different aspects of the

stimulus field were not systematically varied to determine their contribution to performance and to enable the scale of ratios to be usefully interpreted in terms of specific motion sizes.

DISCUSSION OF ERRORS

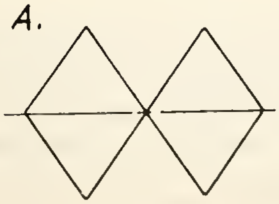
There appears to be a pattern or regularity in the judgment of location. If that percentage of the total number of errors which is due to each stimulus is plotted against stimulus location, as in Graph III, there results a characteristic bimodal distribution which is not symetric with respect to the axes of the stimulus field. Graph IV shows that there is the same kind of distribution for each ratio considered separately. It also appears for both subjects R.A. and J.C. if each one's trials are pooled. The same tendency toward a bimodal error distribution can be seen in the individual results for a number of subjects, though it is by no means universal. The distribution shows two relative maxima, for stimuli one and five, and two relative minima, for four and seven. Both the two maxima and the two minima are approximately opposite on the stimulus circle. There does not seem to be a clear relationship to the ratio used, though the tendency is most marked in the results from ratios three to one and four to one, those for which the operator's hand motion is the largest.

The variation of error frequency with stimulus position cannot be shown to be statistically significant by a simple F ratio tests on the basis of the number of trials that have been made. The large variations among the subjects serves to mask any tendencies of the sort observed. Since the errors are necessarily discrete and have generally skew distributions, the F ratio test is not especially sensitive in this case.

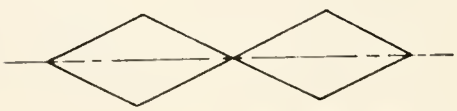
Because of the statistical nonsignificance of the variation of errors with stimulus position, any attempt to account for it is clearly a matter of conjecture and cannot represent a conclusion from the evidence. However, as will be argued below, a cyclic variation like that observed appears reasonable on the basis of other research. This, and the fact that a bimodal error frequency appears for all four ratios in spite of the enormous differences among the subjects and between the ratios themselves indicates, in the writer's judgment, that the matter deserves serious consideration. In what follows, the apparent variation will be treated as a fact, though tentatively, and the possibilities and implications will be explored. Finally, it will be pointed out that, with the particular stimulus pattern and constraints of the experiment, a tendency for hand motions to err in a particular way could partially account for the kind of error distribution observed. Thus, the present experiment may pose an important and interesting question though it cannot resolve it.

Before proceeding further, it would be well to note that to some degree the greater number of errors with stimuli one and eight may be, in part, an artifact of the experimental situation due to the pantograph. When the sensor touches the restraining ring at the top, i.e. near the positions for stimuli one and eight, the operator's hand is at its farthest distance from his body and the links of the mechanism form a pair of flattened parallelograms with their major diagonals along the transverse direction, as in Illustration A below. With the apparatus in this position, the operator encounters somewhat less solid

A.



B.



resistance to an attempt to move his hand farther away than he meets when the sensor is at the opposite location and he tries to move his hand closer to his body. In this latter case, the parallelograms formed by the links are the other way around, as shown in Illustration B. There is no noticable play or looseness in the linkage, but it tends to give somewhat when forced. Judging from experience and the remarks of several of the subjects, the effect is to make the operator less sure of himself even though the display unfailingly informs him whenever the sensor touches the outer circle, and even though the actual give is but a very small fraction of the distance between two possible stimulus locations. Two thirds of the erroneous judgments of stimulus nine place it below the center, a result which might be expected if the give of the mechanism made the upper position of the circle seem farther away. It is quite unlikely that this defect in the linkage can alone account for the excess number of errors occurring with stimuli one and eight. The give in the linkage is greater for higher ratios due to the mechanical advantage and the magnification. It is also greater for higher ratios due to the acute angles of the parallelograms being less, which makes the connected arms approach more nearly a toggle position. But errors made in locating stimuli one and eight account for roughly the same percentage of total errors for every ratio. In fact, the percentage is actually smaller for four to one than for either two to one or three to one. There does not appear to be any characteristic of the linkage which would affect the other stimulus positions unequally.

A relationship between the direction of motion or position of the hand and effective perception of the location of stimuli, as suggested by the data, is not improbable. The most obvious aspect of the hand's environment, its asymetrical attachment to the arm and thus to the body, through joints which are constrained to move only in certain ways, must surely result in peculiarities of function. In at least two cases these have been carefully observed and reported, and the similarities with the present results are quite suggestive.

Corrigan and Brogden (7) found that for linear tracking of a target by a hand held stylus, the precision of the motion was related to the angle of the target path to the body by a sinusoidal function of the form

$$Y = A\sin 2x + B\cos 2x + C$$

In their experiment, the target moved beneath a glass table and the stylus path was restrained by guides which when touched by the stylus registered an error. The measure of precision was the mean number of stylus contacts and reflects deviations transverse to the direction of motion. The angle of the tracking path which was found to give the least number of errors was that at an angle of 140 degrees measured counter clockwise from a line normal to the plane of the subject's body.

A quite different experiment by Begbie (3) gave similar results. It involved having the subjects draw pencil lines from initial points to target points in one sweeping motion. The velocities of the hand were many times greater than in Corrigan and Brogden's experiment. Begbie used not only different angles, but different length lines. The results indicated that the error magnitude was related to angle in a cyclic manner, though a purely sinusoidal function was out of the question. The line for least error was found to be near 145 degrees, quite in accord with the other results.

In the present experiment, the error frequency as a function of stimulus position showed two relative maxima and two relative minima, with stimuli one and either five or six being the maximum locations. If one tentatively accepts that this is a characteristic of the situation and is not due simply to random effects, what is the implication? The implication would seem to be that just as the two experiments mentioned above have shown that combined arm and hand motions vary in accuracy in a cyclic way as their relative directions are changed, so too does the kinesthetically mediated perception of the location

of features of a two dimensional region alter depending on their position with respect to the region's boundaries, and to each other. In view of the fact that other sense modalities often show remarkable field effects, and when it is realized that for the kinesthetic senses performance and perception are entirely interdependent, such a possibility seems reasonable rather than otherwise.

The present experiment did not, for the most part, involve motions in the angular directions associated with the stimulus locations. The motions were mainly along and perpendicular to the axis of the apparatus, at least in intent. Thus, the accuracy with which stimulus location is perceived can be different for different stimulus positions even when the motions used for sensing are of the same kind for each. That this could be so may be indicated by the observation made by Begbie that drawn lines tended to drift toward the direction of least error, a tendency most marked in those lines most nearly in that direction. If the sensing motions tended to drift in this way unknown to the subject, then depending on the configuration of the objective field and its boundary, perceived location could be affected.

Begbie supposes that the existence of a line of least error is due to there being a direction of motion involving the least anatomical complexity of movement, in short an easiest motion. He suggests that this can be demonstrated by holding the upper arm against the body and moving the forearm back and forth so that a pencil held in the hand in front of the body draws a straight line. His argument is certainly plausible, since the easiest line to draw straight is very nearly along the direction he found for the line of least error. He then argues that the errors he found may be accounted for by the subjects tending somewhat to move in this easiest direction even when it is inappropriate. This is the tendency to drift.

If one treats the data summarized in Graph III in the same manner as was done by Corrigan and Brogden and by Begbie, the regularity suggests a line of least error almost seventy degrees away from that found by them. The broken line on the graph shows how a sinusoidal variation in error frequency would appear when shifted to accord with the data. However, the same kind of anatomical argument as above can be followed with the special restraints attendant upon manipulating the remote sensing equipment taken into account. In the two experiments described, the subject could keep his wrist comfortably in line with his forearm, but this was not true in the present case. The subjects using the remote sensing apparatus tended, and were instructed, to keep their right index fingers parallel to the side of the mounting board because it seemed to assist them in keeping track of the longitudinal direction as indicated by their other hand. If the right fist is placed on a table top in front of and just to the right of the body, with the upper arm free to move and the index finger extended and kept pointing straight ahead, the restraints are about the same. If the hand is then moved in a straight line from upper right to lower left, it can be seen that to keep the index finger pointed correctly, the wrist must rotate with respect to the forearm in the plane of the table. This is rather awkward, but motion along a line from upper left to lower right, for which the wrist need not rotate at all, seems to be easiest. This latter direction is more or less that for the line of least error suggested by the present results.

If one assumes that the subjects' hand motions tend somewhat toward the direction of least error, then a possible reason for a bimodal distribution of errors is suggested. This suggestion is developed not so much as an explanation, for there are certainly other factors of importance, but rather as an indication that an approach in terms of relating motor performance to perception of location by kinesthetic senses may be a fruitful one.

It is assumed that there is a tendency for sensing motions to deviate from the longi-

tudinal and transverse directions toward a direction from upper left to lower right. It is further assumed that the subject identifies a stimulus mainly on the basis of the relative distances it appears to have from the restraining circle along what he believes to be the longitudinal and transverse directions toward a direction from upper left to lower right. It is further assumed that the subject identifies a stimulus mainly on the basis of the relative distances it appears to have from the restraining circle along what he believes to be the longitudinal and transverse directions. It is recalled that all of the subjects tended to spend the most time in movements of this sort. Furthermore, it is assumed that the more these relative distances appear to be the same, the more likely he will be to make an error in judgment, except of course for stimulus nine in the center. Under these assumptions, the subject will not be judging the actual distances, but the length of paths at an angle to the main directions. As Figure VIII shows, the actual paths would be canted down to the right from the transverse and longitudinal directions, but they would pass through the stimulus location, since it was used as an anchor and motions were made with respect to it. Due to the circular boundary, the longer of the two apparent distances in either direction for stimuli one, two, five, and six is less than the actual distance, and similarly the shorter appear longer. The reverse holds for the other stimuli and the apparent differences in distance are intensified. Thus on the assumption that as the apparent distances tend to appear the same there is a greater chance for error, stimuli one, two, five, and six would be less often estimated correctly. A bimodal asymmetrical distribution of errors with stimulus location somewhat like that observed would result.

Examination of Figures IV and V shows that the hypothesized drift tendency is certainly not evident for the traces of J.C.'s motion though it might be compatible with those of R.A. There is insufficient evidence for the whole matter, and it is again stressed that the proposed connection between motor performance and perception is in the nature of a potentially useful approach.

CONCLUSION

It has been shown that changing the size of a certain manual task which depends for its successful accomplishment on kinesthetic cues of position can result in marked changes in the quality of performance as measured by the information transmitted from stimulus to response. This has been demonstrated for a case in which all the task sizes are within a range that would usually be considered adequately large for good performance. These results would tend to support the conclusion that for many tasks, especially those requiring gross movements of the hand and arm, there may be an associated optimum size, or size range, which allows the operator to make the best use of his kinesthetic feedback. The nature of the optimum range, its width, sharpness, and location on a scale of absolute size of motion will probably depend on the nature of the task and the kind of discriminations the operator must make. However, in those cases for which the best obtainable performance is desired and for which size can be varied, as in certain remote manipulating equipment, it may be quite worth while to determine the optimum range experimentally to insure that the operator's abilities are fully used.

Comparison of the way errors were made in this experiment with the results of research by Corrigan and Brogden (7) and Begbie (3) suggests that there may be a connection between motor performance and the perception of location mediated by kinesthetic feedback. The peculiarities of performance which Begbie attributes to the way the arm and hand are articulated may influence the motions used in manual exploration in such a way as to distort the apparent spatial properties of the region investigated. This view is not offered as a conclusion, for the evidence does not warrant it, but as a potentially useful hypothesis.

SUGGESTIONS FOR FURTHER RESEARCH

The special virtue of man controlled manipulation and exploration systems is their versatility. Human control enables them to perform an enormous variety of tasks. This variety poses very difficult problems for the engineer who is trying to adapt the mechanism to the man, because people often respond quite differently to apparently similar situations. The number of variables which may influence even the simplest manipulation tasks is very large. This problem arose in the present investigation and has not been met entirely successfully. It is hard to design an experiment involving manipulation which retains a satisfactory amount of practical significance and generality, yet is not open to the criticism that one or another variable has not been adequately controlled.

In consequence of these remarks, it is believed that the research which may prove most useful will be that which is directed toward a better understanding of manipulation itself and toward a clearer definition of the variables involved. A tentative proposal concerning the relation of perception, by means of kinesthesis, to motor performance has already been advanced. It is probably only on the basis of such fundamental work that an adequate investigation of the effect of motion size could be made.

SUMMARY

To obtain the best performance from equipment controlled by a human operator it is necessary that the equipment be designed to enable the person to make the best use of his abilities. Many of the remote manipulators in use in industry, and elsewhere, use a human operator's kinesthetic senses for positioning by duplicating, at the slave end, the operator's motions at the master end of the system. It was sought to determine whether a change in the size of a task, which would amount to a change in size gain in the manipulator, might enable the operator to make better use of his kinesthetic senses, and so result in improved performance. This would surely appear to be true for very small tasks, or extremely large ones; but it was desired to investigate the range of sizes for which the task would normally be considered adequately large.

As a working hypothesis, for lack of clear evidence to the contrary, it was assumed that suitably measured performance as a function of size would show a broad flat maximum over a central range.

Apparatus was used which enabled a subject to explore, by moving his hand and arm, a circular region 2 $\frac{1}{2}$ inches in diameter. The region was fixed in size, but the pantographic apparatus could be adjusted to make the operator's hand motion larger than the sensor motion in a ratio of one, two, three or four to one. The operator was informed of the boundary of the region and of the features within it by means of a tactile display to the fingertip of the active hand. The click associated with the display was found to serve the same purpose practically as well. Movement beyond the boundary was prevented by a metal ring.

The task was to identify, blindfold, one of nine possible locations in the region to be explored. The locations were circular spots 3/16 inch in diameter which were indicated to the subject by the display whenever the sensor passed over them. These stimuli had eight possible positions around a circle of 15/16 inch diameter, with another position in the center. It is argued that this represents a fairly generalized kinesthetic task, and that it has the essential features of a large class of manipulations.

The criterion of performance was the information transmitted from stimulus to response and the analysis was made in terms of multivariate information transmission as developed

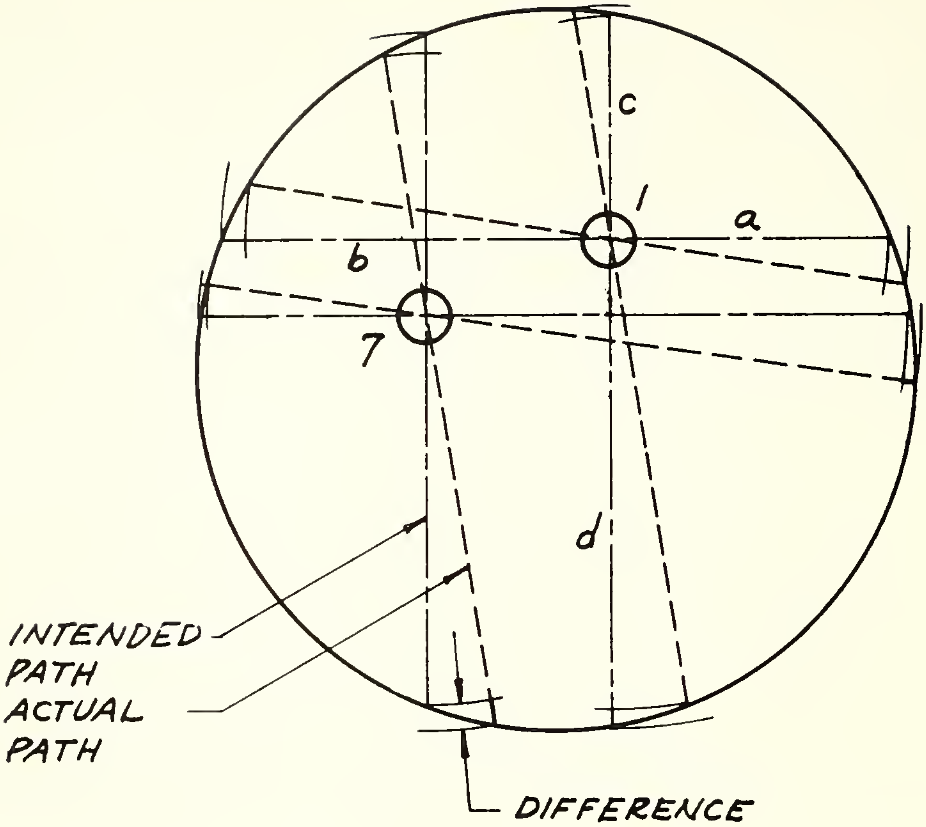


FIGURE VIII: DIAGRAM OF HOW A TENDENCY FOR HAND MOTION TO DRIFT COULD AFFECT THE PROBABILITY OF CORRECT JUDGMENT OF POSITION. THE DIFFERENCE BETWEEN INTENDED AND ACTUAL PATH LENGTH WOULD MAKE a & c SEEM LONGER, b & d SHORTER, MAKING THE LOCATION OF STIMULUS 1, & ALSO 2, 5, & 6 LESS EVIDENT. THE REVERSE APPLIES TO STIMULI 3, 4, 7, & 8.

by McGill (14). An exposition of the method is appended.

Four different subjects were used at each of the ratios. After each was given a training period, he then made 45 determinations of location. The subjects started with the sensor on the spot in question, and they were allowed 50 seconds for each exploration. Different subjects were used at each ratio in the belief that there would be rather large effects of learning if each were to use all the ratios. But the results suggest that the variation among subjects is probably greater than differences that might be expected from learning.

A definite maximum in the transmitted information was observed at the 3:1 ratio, with performance at the 1:1 ratio being the poorest. The interaction of both subjects and ratio with stimuli and responses is significant, with that for subjects being larger. The consistency among the subjects' responses was found to be positively related to performance quality.

The two most skilled subjects performed at all ratios, and their results also show the same kind of relation with ratio as was observed for the others, but at a much higher level, and with a much less pronounced maximum. It was found to be impossible to associate the ratios with particular motion sizes without more information on the nature of the discriminations involved.

It was concluded that a fairly clear maximum in performance might be expected with a remote manipulator if the proper motion size were used. However, this size, for a given task situation, would need to be experimentally determined.

The distribution of errors with stimulus position was also studied. Though the variation was not found to be statistically significant, the persistence of a bimodal distribution, asymmetric with respect to the field, appeared sufficient to warrant its consideration. Similarities with the results of research in motor performance were examined, and a tentative proposal is offered, not so much as an explanation, but as a potentially useful approach in further research.

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STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	1	1					1		1	4
2										0
3		3	1					1	1	6
4				1	1					2
5			1	1	2	2				6
6	1			2		1	1	1	1	7
7		1			1	1	3	2	1	9
8	2				1			1		4
9	1		3	1		1			1	7
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: S. G.
CORRECT: 11
$\hat{T}$(STIM; RESP) = 1.112

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	5									5
2		5								5
3			5							5
4				5						5
5					4	2				6
6					1	3				4
7							5		1	6
8								5		5
9									4	4
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: R. A.
CORRECT: 41
$\hat{T}$(STIM; RESP) = 2.889

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	2	1			1			1		5
2	2	4						1	1	8
3			2		1				3	6
4			1	3	1	1		1		7
5					1					1
6			1	1	1	3	2			8
7	1						2	1		4
8				1						1
9			1			1	1	1	1	5
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: I. K.
CORRECT: 18
$\hat{T}$(STIM; RESP) = 1.345

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1		3						1		4
2		1								1
3			3	1	1					5
4	1	1		2			1			5
5	1		2		1	2			1	7
6				1	1	1	1		2	6
7	2				2		1	2		7
8						1	2	2		5
9	1			1		1			2	5
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: J. B.
CORRECT: 13
$\hat{T}$(STIM; RESP) = 1.398

TABLE I 1:1 RATIO

RESPONSES \ STIMULI	1	2	3	4	5	6	7	8	9	T
1	8	5			1		1	2	1	18
2	2	10						1	1	14
3		3	11	1	2			1	4	22
4	1	1	1	11	2	1	1	1		19
5	1		3	1	8	6			1	20
6	1		1	4	3	8	4	1	3	25
7	3	1			3	1	11	5	2	26
8	2			1	1	1	2	8		15
9	2		4	2		3	1	1	8	21
										180

$\hat{T}$ (STIM; RESP) = 0.985
$\hat{T}$ (SUBJ; RESP) = 0.127
$\hat{A}$ (STIM; SUBJ; RESP) = 0.702
$\hat{T}_{SUBJ}$ (STIM; RESP) = 1.686
$\hat{T}_{STIM}$ (SUBJ; RESP) = 0.828

POOLED TABLE 1:1 RATIO

RESPONSE \ STIMULUS	1	2	3	4	5	6	7	8	9	T
1	3	1								4
2	1	4								5
3			4						1	5
4				5	1					6
5					4	2				6
6						3	2			5
7							1	1		2
8	1							4		5
9			1				2		4	7
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: T. B.
CORRECT: 32
$\hat{T}(STIM; RESP) = 2.281$

RESPONSE \ STIMULUS	1	2	3	4	5	6	7	8	9	T
1				1						1
2	1	3							2	6
3	2		2	1						5
4			2							2
5				2	1	1	1		1	6
6	1			1	1	2	2		1	8
7			1		2	2	2	2		9
8								3		3
9	1	2			1				1	5
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: C. W.
CORRECT: 14
$\hat{T}(STIM; RESP) = 1.392$

RESPONSE \ STIMULUS	1	2	3	4	5	6	7	8	9	T
1	2	2								4
2	1	1								2
3		1	3						1	5
4			2	5						7
5					4					4
6					1	5				6
7							5	1		6
8	1							4		5
9	1	1							4	6
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: R. P.
CORRECT: 33
$\hat{T}(STIM; RESP) = 2.330$

RESPONSE \ STIMULUS	1	2	3	4	5	6	7	8	9	T
1	3									3
2	1	5								6
3			4	1						5
4				4					1	5
5					5	2				7
6						3				3
7							4	1		5
8	1							4		5
9			1				1		4	6
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: K. K.
CORRECT: 36
$\hat{T}(STIM; RESP) = 2.461$

TABLE II 2:1 RATIO

STIMULI

RESPONSES	1	2	3	4	5	6	7	8	9	T
1	8	3		1						12
2	4	13							2	19
3	2	1	13	2					2	20
4			4	14	1				1	20
5				2	14	5	1		1	23
6	1			1	2	13	4		1	22
7			1		2	2	12	5		22
8	3							15		18
9	2	3	2		1		3		13	24
										180

$\hat{T}(STIM; RESP) = 1.664$

$\hat{T}(SUBJ; RESP) = 0.071$

$\hat{A}(STIM; RESP; SUBJ) = 0.452$

$\hat{T}_{SUBJ}(STIM; RESP) = 2.116$

$\hat{T}_{STIM}(SUBJ; RESP) = 0.523$

POOLED TABLE 2:1 RATIO

STIMULUS (columns) / RESPONSE (rows)

	1	2	3	4	5	6	7	8	9	T
1	3									3
2	1	3	2						1	7
3			2							2
4				3						3
5					3	1				4
6						3			1	4
7							4	1		5
8	1	2					1	4	1	9
9			1	2	2	1			2	8
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: S. C.

CORRECT: 27

$\hat{T}(STIM; RESP) = 1.847$

STIMULUS (columns) / RESPONSE (rows)

	1	2	3	4	5	6	7	8	9	T
1	4	1								5
2	1	4							1	6
3			5	1						6
4				3	1				1	5
5				1	2					3
6					2	5			1	8
7							4	1		5
8								4		4
9							1		2	3
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: C. G.

CORRECT: 33

$\hat{T}(STIM; RESP) = 2.250$

STIMULUS (columns) / RESPONSE (rows)

	1	2	3	4	5	6	7	8	9	T
1	5									5
2		5								5
3			5							5
4				5						5
5					5					5
6						5				5
7							5			5
8								5		5
9									5	5
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: J. C.

CORRECT: 45

$\hat{T}(STIM; RESP) = 3.170$

STIMULUS (columns) / RESPONSE (rows)

	1	2	3	4	5	6	7	8	9	T
1	5							1		6
2		5								5
3			5	1						6
4				4	1					5
5					4	1				5
6						4				4
7							5	2		7
8								2		2
9									5	5
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: H. D.

CORRECT: 39

$\hat{T}(STIM; RESP) = 2.702$

TABLE III 3:1 RATIO

STIMULI

RESPONSES	1	2	3	4	5	6	7	8	9	T
1	17	1						1		19
2	2	17	2						2	23
3			17	2						19
4				15	2				1	18
5				1	14	2				17
6					2	17			2	21
7							18	4		22
8	1	2					1	15	1	20
9			1	2	2	1	1		14	21
										180

$\hat{T}$ (STIM; RESP) = 2.213
$\hat{T}$ (SUBJ; RESP) = 0.062
$\hat{A}$ (STIM; RESP; SUBJ) = 0.279
$\hat{T}_{SUBJ}$ (STIM; RESP) = 2.492
T_{STIM} (SUBJ; RESP) = 0.341

POOLED TABLE 3:1 RATIO

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	1							1		2
2	4	3								7
3		1	4						2	7
4			1	3						4
5				1	4	4				9
6						1				1
7					1		3			4
8							2	3		5
9		1		1				1	3	6
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: K. J.
CORRECT: 25
$\hat{T}$(STIM; RESP) = 1.988

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	3									3
2		1	1					1		3
3		3	1	1						5
4			2	4	1				1	8
5					2	2				4
6					2	2			1	5
7						1	3	1		5
8	1						1	3		5
9	1	1	1				1		3	7
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: J. V.
CORRECT: 22
$\hat{T}$(STIM; RESP) = 1.707

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	4	1								5
2	1	3	1							5
3			4							4
4				5						5
5					1					1
6					3	4				7
7						1	4			5
8							1	5		6
9		1			1				5	7
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: B. G.
CORRECT: 35
$\hat{T}$(STIM; RESP) = 2.439

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	4							1		5
2	1	4								5
3		1	4							5
4			1	4	1					6
5				1	4	1				6
6						4	1			5
7							4	1		5
8								3		3
9									5	5
T	5	5	5	5	5	5	5	5	5	45

SUBJECT: D. S.
CORRECT: 36
$\hat{T}$(STIM; RESP) = 2.435

TABLE IV 4:1 RATIO

STIMULI

RESPONSES	1	2	3	4	5	6	7	8	9	T
1	12	1						2		15
2	6	11	2					1		20
3		5	13	1					2	21
4			4	16	2				1	23
5				2	11	7				20
6					5	11	1		1	18
7					1	2	14	2		19
8	1						4	14		19
9	1	3	1	1	1		1	1	16	25
										180

$\hat{T}(STIM; RESP) = 1.796$
$\hat{T}(SUBJ; RESP) = 0.083$
$\hat{A}(STIM; RESP; SUBJ) = 0.346$
$\hat{T}_{SUBJ}(STIM; RESP) = 2.142$
$\hat{T}_{STIM}(SUBJ; RESP) = 0.429$

POOLED TABLE 4:1 RATIO

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	5	1								6
2		4								4
3			5							5
4				5						5
5					5					5
6						5				5
7							5	1	1	7
8								4		4
9									4	4
T	5	5	5	5	5	5	5	5	5	45

TRIAL 3
RATIO: 1:1
CORRECT: 42
$\hat{T}$(STIM; RESP) = 2.905

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	5									5
2		5							1	6
3			5							5
4				5						5
5					5					5
6						5				5
7							5			5
8								5		5
9									4	4
T	5	5	5	5	5	5	5	5	5	45

TRIAL 4
RATIO: 2:1
CORRECT: 44
$\hat{T}$(STIM; RESP) = 3.083

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	5									5
2		5								5
3			5							5
4				5						5
5					5					5
6						5				5
7							5			5
8								5		5
9									5	5
T	5	5	5	5	5	5	5	5	5	45

TRIAL 1
RATIO: 3:1
CORRECT: 45
$\hat{T}$(STIM; RESP) = 3.170
THIS IS SAME DATA AS IN TABLE III

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	3							1		4
2	2	5								7
3			5							5
4				5	1					6
5					4					4
6						5				5
7							5			5
8								4		4
9									5	5
T	5	5	5	5	5	5	5	5	5	45

TRIAL 2
RATIO: 4:1
CORRECT: 41
$\hat{T}$(STIM; RESP) = 2.877

TABLE V SUBJECT J.C., 50 SEC. LIMIT

STIMULI

RESPONSES	1	2	3	4	5	6	7	8	9	T
1	18	1						1		20
2	2	19							1	22
3			20							20
4				20	1					21
5					19					19
6						20				20
7							20	1	1	22
8								18		18
9									18	18
										180

$\hat{T}(STIM; RESP) = 2.924$

$\hat{T}_{RATIO}(STIM; RESP) = 3.009$

$\hat{A}(STIM; RESP; RATIO) = 0.085$

POOLED TABLE SUBJECT J.C.

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	4	1								5
2		4	1							5
3			4							4
4				4	1					5
5				1	4					5
6						5				5
7							4	3		7
8	1							2		3
9							1		5	6
T.	5	5	5	5	5	5	5	5	5	45

TRIAL 3
RATIO: 1:1
CORRECT: 36
$\hat{T}(STIM; RESP) = 2.548$

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	4									4
2		5								5
3			5							5
4				5						5
5					5	1				6
6						4				4
7							5	1		6
8								4		4
9	1								5	6
T	5	5	5	5	5	5	5	5	5	45

TRIAL 4
RATIO: 2:1
CORRECT: 42
$\hat{T}(STIM; RESP) = 2.910$

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	3									3
2		5								5
3			5							5
4				5						5
5					5					5
6						5				5
7							5	1		6
8	1							4		5
9	1								5	6
T	5	5	5	5	5	5	5	5	5	45

TRIAL 5
RATIO: 3:1
CORRECT: 42
$\hat{T}(STIM; RESP) = 2.916$

STIMULUS

RESPONSE	1	2	3	4	5	6	7	8	9	T
1	3	1								4
2		4								4
3			4							4
4			1	5						6
5					4					4
6					1	5	1			7
7							4	1		5
8	2							4		6
9									5	5
T	5	5	5	5	5	5	5	5	5	45

TRIAL 2
RATIO: 4:1
CORRECT: 38
$\hat{T}(STIM; RESP) = 2.630$

TABLE VI SUBJECT R.A., 20 SEC. LIMIT

STIMULI

RESPONSES	1	2	3	4	5	6	7	8	9	T
1	14	2								16
2		18	1							19
3			18							18
4			1	19	1					21
5				1	18	1				20
6					1	19	1			21
7							18	6		24
8	4							14		18
9	2						1		20	23
										180

$\hat{T}$ (STIM ; RESP) = 2.628
$\hat{T}_{\text{RATIO}}$ (STIM; RESP) = 2.751
$\hat{A}$ (STIM; RESP; RATIO) = 0.123

POOLED TABLE SUBJECT R.A.
(20 SEC. LIMIT)

STIMULI

RESPONSES	1	2	3	4	5	6	7	8	9	T
1	45	10		1	1		1	5	1	64
2	14	51	4					2	5	76
3	2	9	54	6	2			1	8	82
4	1	1	9	56	7	1	1	1	3	80
5	1		3	6	47	20	1		2	80
6	2		1	5	12	49	9	1	7	86
7	3	1	1		6	5	55	16	2	89
8	7	2		1	1	1	7	52	1	72
9	5	6	8	5	4	4	6	2	51	91
										720

$\hat{T}$ (STIM; RESP) = 1.432

$\hat{T}_{RATIO}$ (STIM; RESP) = 1.664

$\hat{T}_{SUBJ}$ (STIM; RESP) = 2.109

$\hat{A}$ (STIM; RESP; RATIO) = 0.232

$\hat{A}$ (STIM; RESP; SUBJ) = 0.677

POOLED TABLE ALL RATIOS

STIMULUS VARIABLES IN AUDITORY PROJECTIVE TESTING

by

Harvey Jay Kramer

EDITOR'S NOTE:

The present paper represents Chapter 3 of a Doctors' Dissertation of the above title, submitted to the University of Rochester, 1961.

Chapter 3 - THE PROJECTION STUDY

Introduction. The concept of stimulus ambiguity as an important psychological variable was discussed in Chapter 1 in relation to its role in personality theory, psychotherapy, and with respect to the theory of projective techniques. In this latter regard, it was noted that ambiguity in the projective test situation is deliberate in order to create a stimulus field which allows for the widest variability of responses and elicits the most extensive personality information. The literature relevant to the study of the relationship between stimulus ambiguity and projection was also reviewed in Chapter 1. This research has demonstrated that the variable of ambiguity is a prime stimulus factor in eliciting personality information from projective materials.

Some of these studies (Weisskopf, 1950; Weisskopf-Joelson and Lynn, 1953) measured ambiguity in terms of physical variations of TAT and CAT pictures (e.g., incompleted line tracings). Other studies, including Bijou and Kenny, 1951; Kenny and Bijou, 1953; Kenny, 1954; Murstein, 1958b, measured ambiguity in terms of psychological variations of the stimulus by computing the number of interpretations a group of judges had estimated would apply to each TAT card. Criticism of this procedure and the presentation of a new method for obtaining ambiguity values from thematic apperception stimuli were reported in Chapter 2.

The results of the studies concerning the relationship between psychological ambiguity and projection have bearing on the present investigation. The findings showed a significant curvilinear relationship indicating that with increasing ambiguity there was an initial increase in the production of personality information and then a decrease. It was found that TAT cards in the intermediate range of ambiguity elicited maximum projection, while cards in the least and most ambiguous ranges revealed minimum projection.

In addition to the review of research on the effects of varying degrees of ambiguity upon projection, relevant literature concerning variations in stimulus content and their relation to the interpretation of projective responses was also reported in Chapter 1. Studies with children comparing the animal figures of the CAT with human approximations showed the superiority of human content over animal content in eliciting personality information.

The writer believes that the variable of content may be no less a determinant of projective response to auditory projective material than it is to visual material. The number of sounds and combination of sounds which have been recorded in auditory tests are many and varied, although different tests contain some similar sounds but usually with

different background affects. In order to evaluate systematically the effects of content upon projection, the sounds used in this study were selected to meet the criteria for placement in one of two categories, human and non-human sound content.

It was noted earlier that the curvilinear relationship between ambiguity and projection was obtained with TAT stimuli, which are almost entirely of human content. One step in testing the limits of lawfulness of this relationship would be to examine it against results obtained by using stimulus materials of non-human content. A question asked in this study is: Would the relationship between ambiguity and projection be the same for human and non-human content, or is the relationship more complex, requiring some modification to include the effects of the content variable?

A further step in clarifying the lawfulness of this relationship would be to ascertain whether the results obtained from visual stimuli can be repeated in a different sensory modality. Audition was selected for this purpose because available auditory projective stimuli possess a good assortment of human and non-human content and can be easily adapted to thematic apperception analysis.

The auditory projective method is useful in personality evaluation of the blind, for whom audition is a critical interpersonal sensory modality. This method also has promise as a fruitful technique for use with the sighted, and may be comparable in value to such visual tests as the TAT. Both blind and sighted persons served as Ss in the study, the blind providing an additional variable of cross-validation for assessing the relationship between varying ambiguity and projection.

Relevant to the present investigation and a practical reason for studying this experimental relationship, is the question of developing a more scientific method of construction and clinical application of projective techniques in general and auditory techniques in particular. The auditory projective tests which have been published represent a potpourri of approaches not usually developed from sound theoretical principles or experimental data. Reviewing the tests in this field, Lebo and Bruce (1960) aptly referred to them as having been designed by "intuitive cerebration" rather than by scientific methods. These authors suggested the need for a comparative investigation of the recorded auditory projective tests.

The feeling of the writer, however, is that it would be more fruitful, in establishing the adequacy of auditory projective techniques in the scientific community, to study the effects of internal auditory stimulus properties upon projection rather than to make comparative studies of the existing heterogeneously composed tests. The need is to develop an understanding of the various stimulus components, how and why they work, and their differential and interactional effects upon projection. None of these questions would seem to be effectively explored by comparative studies of the existing tests.

The approach to the problem by investigating stimulus properties of auditory projective tests, especially when these properties are peculiar to projective tests in general, would contribute to the basic theory of projective techniques as well as provide an experimental foundation for auditory techniques. The present study was designed to meet this need.

The relationship between varying psychological ambiguity and projection was investigated using auditory projective stimuli representing low, intermediate and high ambiguity and composed of human and non-human content. The interactional effects of stimulus ambiguity and content upon projection and the effects of blindness upon these relationships were measured.

Methodology. Subjects: The Ss consisted of 20 sighted and 20 adventitiously blind adult males. Selection was based on an attempt to match the population of the Ambiguity Study

in terms of age, educational achievement, and intelligence as measured by the Wechsler-Bellevue vocabulary score. Table 8 summarizes the comparative data. Informal consideration was given to matching for socio-economic characteristics. The blind Ss, as in the Ambiguity Study, were either totally blind or had light perception only. Criteria used for selection were the recommended definitional standards of the American Foundation for the Blind, reported in Appendix A. The blind Ss were obtained through the cooperation of the Buffalo Association for the Blind. Individuals having a known history of serious emotional disturbance or mental retardation were excluded from the sample. The sighted Ss were obtained from various community resources, including The Lions Club, Parent-Teacher Associations, and from individual referrals.

Table 8

Equation of Blind and Sighted Groups in the Projection Study

Group	Mean Age	Age Range	Mean Educational Level in Years	Mean Vocabulary Raw Score
Blind (N = 20)	34.45	19-53	11.10	23.50
Sighted (N = 20	31.20	19-47	12.50	24.25

Note.--The Ss were selected so as to match the Ss of the Ambiguity Study. Data on the control variables of the Ambiguity Study are found in Table 2.

Procedure. The 18 projective stimuli which were selected in the Ambiguity Study for use in this investigation were administered individually to each of the 40 Ss. The items were presented in different random orders so as to eliminate placement effects. The experimental sessions took place in the homes of the Ss (mostly blind) and in conference rooms of several community buildings (Crane Branch of the Buffalo Public Library, Buffalo Association for the Blind, and Moose Club, Lancaster, N.Y.). The average length of each session was one hour and forty-five minutes. This varied according to the productivity and expressive skills of the individual. The E operated the phonograph and recorded in longhand the thematic stories obtained from each S.

The auditory stimuli were administered with a modified version of the standard instructions given for the visual stimuli of the TAT. Each S was asked to make up as dramatic a story as possible suggested from the sounds he had heard, not just to describe the sounds, but to relate a complete story telling what led up to the event portrayed by the sounds, what was happening and to give the outcome (see Appendix E for full instructions).

Upon completion of the experimental procedure, 40 sets of 18 stories had been collected. The protocols were then sorted and placed under stimulus headings so that the 40 stories obtained from both blind and sighted Ss to each stimulus were grouped together. The resulting distribution was 18 stimulus sets of 40 stories each.

Measurement of Projection. Projection was judged by two clinical psychologists who rated each story on the basis of qualitative personality information revealed about the S. The judges were instructed to consider any story content which revealed or suggested some dynamic facet of personality structure (e.g., attitudes, motives, defenses, conflicts).

A system of coded numbers on the protocols was used to identify the sighted and blind Ss to the E, while concealing information about visual status from the judges.

The judges assigned a projection score to each story in terms of a seven-point rating scale. The scale rated projection on a continuum of increasing degrees of significant personality information. Scale values ranged from simple stimulus description (numerical rating: one) to the seventh category denoting projection of very significant personality material (e.g., definite evidence of main defense mechanism, central character trait, pathology). Thus, stories judged to contain significant or genotypical personality information were given greater weight than stories which appeared to reflect insignificant or phenotypical personality information. The rating scale and instructions to judges are presented in Appendix F.

The basic task of each judge was to assign projection scores to nine stimulus items or a total of 360 stories. The stimuli were apportioned so that the nine items which each judge rated consisted of three each from the low, intermediate and high levels of ambiguity. The human and non-human items were distributed to the judges as equally as possible so that each judge rated five of one type of content and four of the other type.

In addition to their assigned sets of nine items, one judge rated one item and the other two items from each other's set. The three independently rated items, consisting of 40 stories each, provided an N of 120 for the purpose of conducting a reliability study.

The total projection score for each stimulus item was obtained by adding the numerical ratings given to the 40 stories. Projection scores for blind and sighted Ss on each item were derived by the same method based on Ns of 20. By adding the scores of appropriate individual items, differential measures of projection were obtained for human and non-human stimuli and for the categories of low, intermediate and high ambiguity.

Results and Discussion. The test for inter-judge reliability was based on the independent ratings the judges gave to the 120 projective stories of items W-I-5, BC-IV-6 and W-I-1, each randomly selected from one of the three levels of ambiguity. One judge rated W-I-5 and BC-IV-6 and the other rated W-I-1, in addition to their assigned nine items. The product-moment correlation coefficient was .72, which is significant at the .001 level of confidence.

The investigation of the relationships between ambiguity, content, and projection was carried out with two main experimental effects: three levels of ambiguous auditory stimuli (low, intermediate, and high) and two types of auditory stimulus content (human and non-human). These two main effects were repeated with both blind and sighted Ss. This 3 x 2 x 2 factorial analysis of variance was performed according to the Type VI design outlined by Lindquist (1953).

The analysis of variance results are shown in Table 9. The means are presented in Table 10. The sighted Ss tended to give more personality information than the blind Ss, but the F was insignificant ($.20 p < .10$). This shows that visual status did not significantly affect the amount of projection revealed in the 18 experimental projective stimuli.

The F for the main effect of ambiguity level was significant beyond the .05 level of confidence. This result indicates significant differences between the three levels of psychological ambiguity in their effect upon the amount of projection elicited from auditory projective materials.

Figure 1 shows the over-all relationships between increasing ambiguity and projection. T tests were made between the low and intermediate, high and intermediate, and low and high

sets of stimuli. It can be seen from Table 11 that projective output increased markedly between the low and intermediate levels of ambiguity. Statistical significance was well beyond the .01 level for the t of 3.49. Projection decreased between the intermediate and high levels of ambiguity, but the t of 1.66 was not significant. The mean difference between low and high ambiguity was also not significant.

Table 9

Analysis of Variance of Projection Scores

Source of Variation	df	Sum of Squares	Mean Square	F
Between Ss	39	1013.80		
Visual Status	1	53.20	53.20	2.10[a]
Error (between)	38	960.60	25.28	
Within Ss	200	975.50		
Ambiguity	2	48.40	24.20	4.78[c]
Content	1	53.20	53.20	13.75[d]
Ambiguity X Content	2	31.10	15.55	4.06[c]
Ambiguity X Vision	2	1.80	.90	<1
Content X Vision	1	12.60	12.60	3.26[b]
Ambiguity X Content X Vision	2	5.60	2.80	<1
Error (w)	190	822.80	4.33	
Error (w)	76	384.80	5.06	
Error (w)	38	147.00	3.87	
Error (w)	76	291.00	3.83	

[a]$p < .20$, [b]$p < .10$, [c]$p < .05$, [d]$p < .001$

Table 10

Table of Means

Ambiguity Level	Type of Content	Subjects: Blind	Sighted	Both
Low	Human	3.15	3.62	3.38[a]
	Non-human	2.82	2.82	2.82[a]
	Both	2.98	3.22	3.10
Intermediate	Human	3.37	3.95	3.66[b]
	Non-human	3.20	3.35	3.27[b]
	Both	3.28	3.65	3.46
High	Human	3.10	3.45	3.27[c]
	Non-human	3.12	3.45	3.28[c]
	Both	3.11	3.45	3.28
	Total	3.12[d]	3.44[d]	

[a]Human content is .56 higher than non-human. Significant at the .001 level of confidence.
[b]Human content is .39 higher than non-human. Significant at the .05 level of confidence.
[c]No significant difference between human and non-human content.
[d]No significant difference between the blind and sighted groups.

Table 11

t Tests for Projective Differences at Mean Ambiguity Levels

Ambiguity Level	Mean Scale Value	Mean Difference	t
Low vs. Intermediate	3.10 3.46	.36	3.49*
Intermediate vs. High	3.46 3.28	.18	1.66
Low vs. High	3.10 3.28	.18	1.44

*Significant at the.01 level of confidence.

It can be stated, at this point in the discussion, that the data representing the over-all relationship between ambiguity and projection confirm previous results obtained with TAT cards only to the extent that with increasing psychological ambiguity there is an initial increase in the amount of projection and then a decrease. The data, however, do not support the findings of earlier studies that stimuli from the intermediate ambiguous range reveal significantly more personality information than stimuli from the high range of ambiguity, although the results were in the same direction ($p < .10$). As was noted, a significant increase in projection was shown between low and intermediate ambiguity, but the decrease in projection between intermediate and high ambiguity was statistically insignificant. The analysis of the interaction between content and ambiguity, discussed below, will provide an explanation of why the decrease in projection between the intermediate and high levels was not significant.

The F for the main effect of content was significant beyond the .001 level of confidence. Auditory projective stimuli with human content elicited a significantly greater amount of qualitative personality information than stimuli with non-human content.

The analysis of variance reveals a significant interaction between content and ambiguity level. Figure 2 shows that human content yielded significantly more projection than non-human content at low ambiguity ($p < .001$) and again at intermediate ambiguity ($p. < .05$). There was, however, no difference in the amount of projection between the human and non-human items at the level of high ambiguity. While the results reflect the composite projection scores of the blind and sighted populations, it is interesting to note from the content by vision interaction, shown in Figure 3, that for each group almost identical scores were obtained on the high ambiguous human and non-human items. This finding provides further support for the conclusion of no projective differentiation at this level on the basis of content.

It may be asked why the stimulus cues emanating from human content or situations of an interpersonal nature, which facilitated significantly more projection than non-human items at low and intermediate ambiguity, do not have the same differential projective "pull" at high ambiguity. If anxiety and stress are increased as situations become increasingly vague, as suggested by some investigators (Cameron and Magaret, 1951), it appears to the writer that projective stimuli which convey human situations and are exceed-

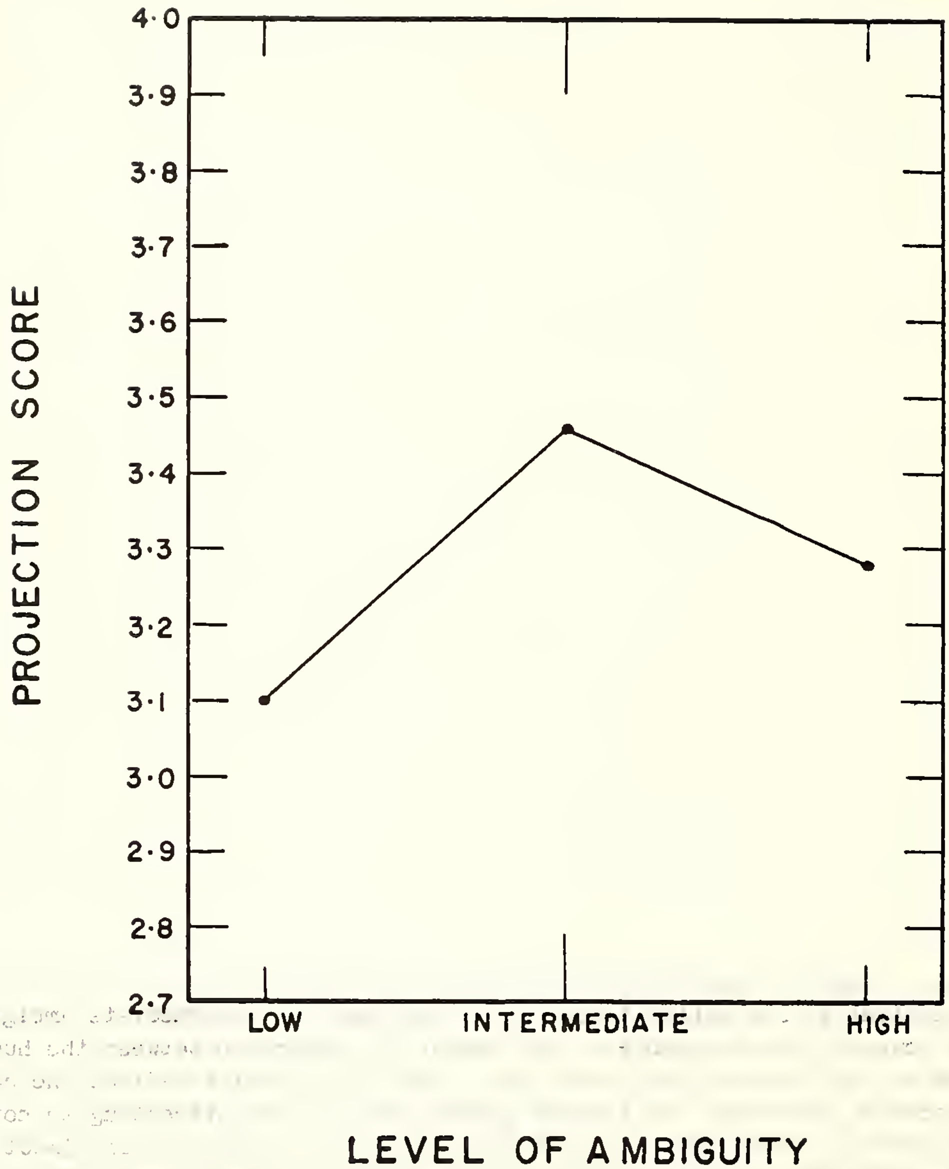

FIGURE I. OVERALL RELATIONSHIP BETWEEN AMBIGUITY AND PROJECTION.

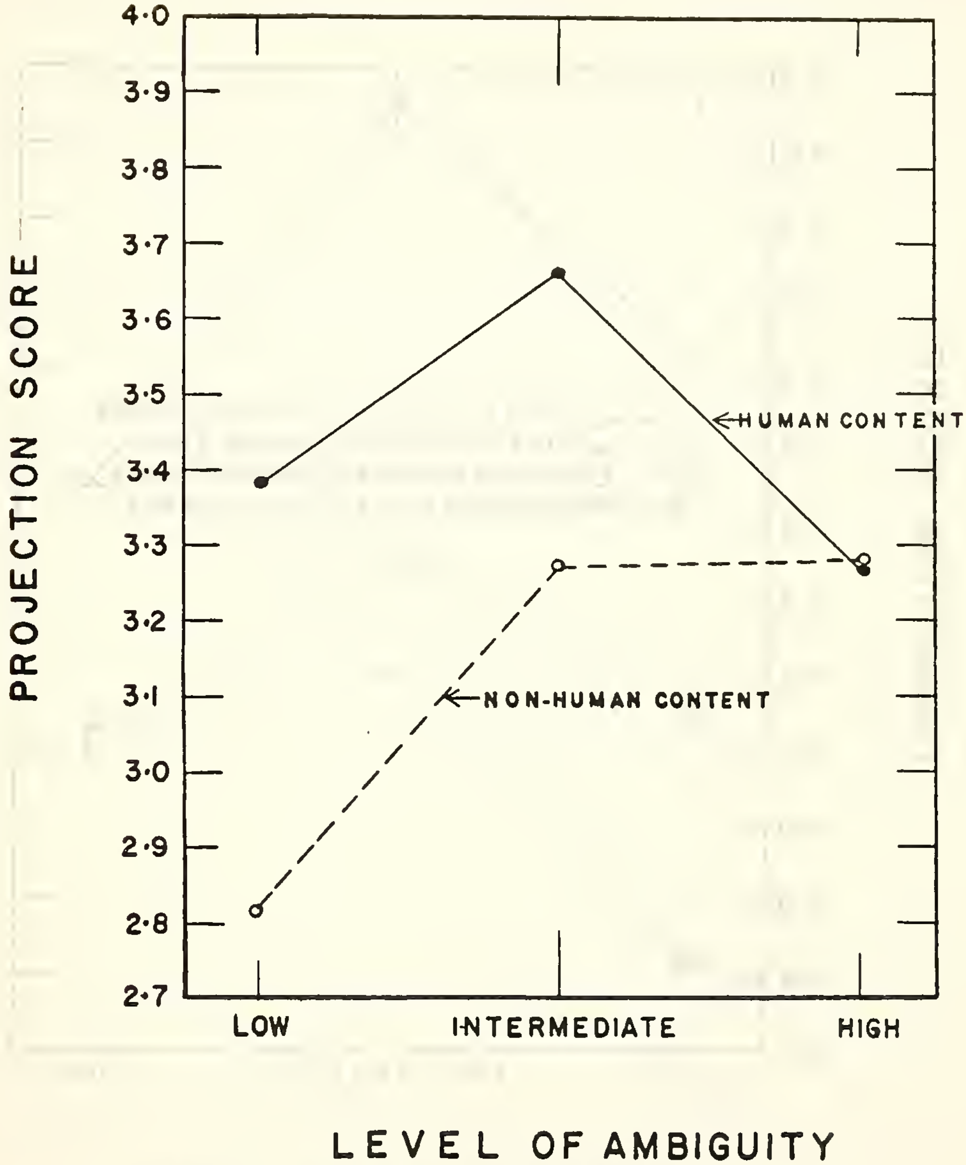

FIGURE 2. PROJECTION CURVES SHOWING THE INTERACTION BETWEEN CONTENT AND AMBIGUITY LEVEL.

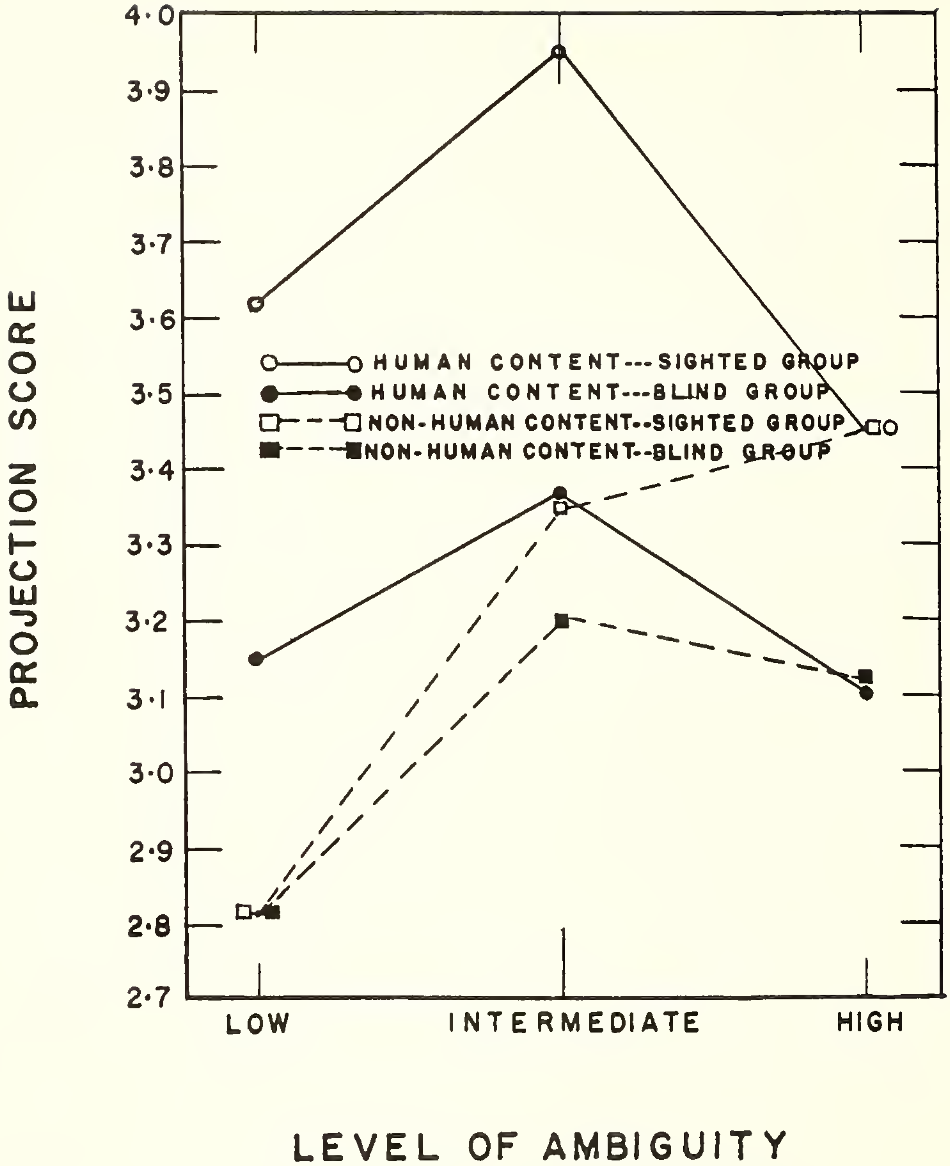

FIGURE 3. PROJECTION CURVES SHOWING THE INTERACTION BETWEEN CONTENT, VISUAL STATUS, AND AMBIGUITY LEVEL.

ingly ambiguous could arouse the most anxiety and operate to increase ego defensiveness and to lower fantasy production.[2] In comparison, intermediate ambiguous human stimuli may arouse just sufficient anxiety and perceptual responsiveness to mobilize, rather than inhibit, unconscious identifications and fantasy production. The stimulus-dominated low ambiguity items, other things being equal, would appear to elicit the least anxiety and leave little room for internal drives and response tendencies to be expressed.

It can be seen in Figure 2 that the projection curves for both human and non-human content show a similar rise between the low and intermediate levels of ambiguity. The high agreement between these two independent variables confirms the finding that as ambiguity increases from the most structured stimuli to intermediate ambiguous stimuli there is a concurrent increase in the amount of significant personality information revealed.

An interesting change in the shape of the human and non-human curves takes place between the intermediate ambiguity level and high ambiguity. The amount of projection evoked from human content in the most ambiguous set was significantly less than the projection obtained from the human intermediate set ($p < .05$). In fact, the decrease in projective output between intermediate and high ambiguity was such that the high ambiguity items produced slightly less projection than the low ambiguity set. On the other hand, the amount of projection elicited from non-human content was unchanged between the intermediate and most ambiguous sets. Thus, the variable of stimulus content has a significant effect upon the relationship between ambiguity and projection, its greatest effect occurring between the intermediate and high levels of ambiguity.

These results clearly indicate why the contention that intermediate ambiguous stimuli elicit significantly more projection than stimuli in the least and most ambiguous sets was not supported in this investigation. The constancy of projection scores on the non-human items in the intermediate and high ambiguity levels offset the significant decrease in projection between the same ambiguity levels on the human items. The result, as shown in Figure 1, was an over-all decline in the production of personality information from the intermediate to the high ambiguity level, which was not statistically significant.

An important question which arises and is basic to the study is: How are the present findings related to the previous studies with TAT cards which found a significant decrease in projection between intermediate and high ambiguity? Paradoxical as it may seem, the findings of this study actually confirm those of studies which employed visual stimuli from the TAT. This is true because it was demonstrated that the relationship between varying ambiguity and projection was significantly curvilinear only when the auditory projective stimuli were composed of human content. In this respect, of the 31 Murray TAT cards, all but four cards have human content. It is not inconsistent, therefore, that in the present investigation only the ambiguity-projection curve derived from human content items confirmed the original significant curvilinear relationship.

The results indicate that a statement of the lawful relationship between ambiguity and projection should include the significant effect of stimulus content. The study not only demonstrated the previously evidenced relationship between varying ambiguity of human content and projection, but provided additional dimensions of cross-validation since the data were obtained through a different sensory modality, audition, and from blind as well as sighted individuals. In showing that experimental relationships derived from visual stimuli can be repeated with auditory stimuli, the findings bode well for the future use of auditory stimuli in research and projective testing

Summary. The hypothesis that intermediate ambiguous stimuli yield significantly more personality information than stimuli from either the low or high levels of ambiguity, was in part rejected. An important finding of the study was to show that the relationship between psychological ambiguity and projection is significantly influenced by the variable of

stimulus content.

The relationship was significantly curvilinear only when stimuli composed of human content were used. It has been demonstrated under various experimental conditions (visual and auditory materials, sighted and blind persons), thus providing additional support for the lawfulness of this curvilinear relationship within the general theory of projective techniques.

Auditory projective stimuli with human content produced significantly more projection than stimuli with non-human content. The data confirm and enlarge upon similar findings from the CAT literature showing the superiority of human over animal content.

The projection curve for non-human content also increased significantly between the least and intermediate ambiguous sets of auditory stimuli, but the amount of projection evoked from the intermediate and most ambiguous sets was the same, and the curve remained level between these sets. No difference was evidenced between human and non-human items at high ambiguity. In fact, both blind and sighted Ss each obtained almost identical projection scores on the highly ambiguous human and non-human items. The over-all relationship between ambiguity and projection, with pooled Ss and content, showed a significant increase in projection between low and intermediate ambiguity, and then a decrease in projection between the intermediate and high ambiguity levels, which was not statistically significant.

An explanation was given for the finding that human content items, which elicited significantly more projection than non-human items at low and intermediate ambiguity, did not yield differential results at the high ambiguity level. It was suggested that highly ambiguous projective stimuli which portray situations of an interpersonal nature can arouse inordinate anxiety and operate to increase ego defensiveness and lower fantasy production. On the other hand, intermediate ambiguous stimuli may arouse a moderate amount of anxiety, enough to increase perceptual responsiveness and mobilize fantasy production. The stimulus-dominated low ambiguity items, which tend to allow "safe" descriptive responses, are believed to produce the least anxiety and the lowest expression of internal drives and projective responses. This hypothesis of a linear relationship between stimulus ambiguity and anxiety level should be investigated. Systematic study of the effects of varying ambiguity upon anxiety and perceptual response tendencies can be important for personality theory as well as projective test theory.

PROJECTIVE METHODS RECOMMENDED FOR USE WITH THE BLIND

by

Dell Lebo and Roselyn Sherman Bruce

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A. INTRODUCTION

The number of projective tests actually used or recommended for use with blind individuals is difficult to determine. It has been described as "deficient" (Braverman & Chevigny, 1955, p. 2), "severely limited" (Lebo & Harrigan, 1957, p.339), and "scant" (Morris, 1950, p. 114). Dean, in a study "concerned (in part) with the problems of just what tests to use in evaluating adjustment to blindness" (1957, p. 171) used only two projective tests; while the originator of a new tactile projective device for the blind remarked cryptically that no other projective technique than his was available for the testing of blind subjects.[1]

A more mysterious sequence of test recommendations and references has its start in a section on the psychological examination of blind persons in a recent text on testing procedures (Anastasi, 1957). That section served to recommend a manual on testing the blind psychologically (Bauman & Hayes, 1950) which devoted one sentence to projective techniques. The manual, in turn, cited a chapter in a book (Morris, 1950) based on a 1947 conference.

This chapter seems to have been the only attempt actually to list and describe suitable tests. The review cited only nine projective tests, one of which apparently has not yet appeared in published form. Since the enumeration appeared the projective testing of the blind has, according to two observers, "undergone a noticeable development" (Raskin & Weller, 1953, p. 18). The present writers now agree. New projective tests have been reported in the literature, several of the older tests actually have been used with the blind, and normative and validating studies on blind and sighted subjects have appeared.

Previous work on techniques deemed suitable for use with the blind has been available in publications largely intended for counselors of the blind. The general literature of psychology contains only scattered references to individual tests and experiments. Since any clinical psychologist may be called upon to test a partially sighted or blind person, and many experimental psychologists may be interested in utilizing such people as research subjects, the present writers believe that a current evaluation of the field is needed.

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[1] E. F. Kerman, personal communication, May 26, 1958. Since the present review was accepted for publication this statement has appeared in an article not listed among the references (Kerman, E. F. Cypress knees and the blind. J. Proj. Tech., 1959, 23, 49-56.) In that article the statement has been amplified and apparently restricted to forms that can be explored tactually since "earlier efforts were not carried very far..."(p.56).

In addition to describing projective methods suitable for the psychological examination of the blind or partially sighted, the present paper also evaluates the field, indicating seeming weaknesses in an abandoned proliferation of stimuli, and suggesting what seems to be a much needed long range program of research. This evaluation schema might well be useful throughout the realm of projective psychology.

B. AUDITORY PROJECTIVE TESTS: STIMULI READ

Auditory techniques in projective testing are of especial interest because they may also be used by any person who can hear, without regard to visual defects. So they have the possibility of being important additional, but little known, tools for clinical or research work on sighted individuals as well as blind.

1. Insight Test. One such method, the Insight Test (Sargent, 1953) originally developed for use with sighted persons, has aroused interest as a useful projective technique for the blind. First described in a monograph published in 1944 (Sargent, 1944) it has been regularly employed as one of a battery of tests used in evaluating the adjustment potential of blind persons undergoing rehabilitation training (Sargent, 1956).

The Insight Test consists of a series of briefly described situations somewhat resembling Murray's (1943) verbal descriptions of the Thematic Apperception Test (TAT) pictures. At present the Insight Test consists of four forms, each with 15 psychological situations described. While as yet there have been no specific problems introduced into the test for blind subjects (Sargent, 1953, p. 227), the following statement is an example of the type of verbal picture suggested for such use: "A woman who has been blinded in an accident receives a letter from her daughter asking her to come to live in her home."

Subjects are instructed to analyze what people do and feel under the circumstances set forth. They are also told that there are no right or wrong answers but that they should show insight into the actions of the characters.

Sargent (1953) realized that an unlimited number of problems could be concocted for blind individuals. However, she cautioned against using more than a few in an Insight Test. She advocated, instead, a majority of regular questions so that the examiner's experience with the original material could be put to advantage to judge alterations in form and content when personal problems were approached. She also surmised "that questions about deafness, for example, or other handicaps, might be used in forms for blind persons...since experience has shown that in some instances attitudes embedded in highly sensitive areas appear less disguised when the projective figure is somewhat remote" (Sargent, 1953, p. 228).

Examples of the use of 10 items of the Insight Test on two blind persons are available with full protocols and analyses (Sargent, 1953). Methods of analysis, as is so often the case in projective psychology, range from content analysis to a "cumbersome" (Sargent, 1953, p. ix) formal procedure. The latter scoring system involves differentiating between expressions serving to control, defend, or delay unmodulated emotions. The subjects' phrases are categorized with regard to the outcome of aroused affect and expressed mood. Relationships between some expressions said to represent affect and defense or discharge or control may be computed. In addition, Sargent expects the "clinical research worker" to "take creative liberties with....the method of analysis..."(1953, p. ix). One such worker has developed a simpler system (Fassett, 1948).

Another worker, who collected 75 or more records from blind subjects, reported that the Insight Test was "the most promising method presently available (1947) for research with the blind" (Morris, 1950, p. 125). Dean, however, comparing Sargent's findings with

protocols from 54 blind persons, concluded "that the Insight patterning of answers suggests a cautious use of (Sargent's) norms with the blind" (1957, p. 177). Sargent herself, in a study of 27 blind persons, called attention to "the danger of relying, at this stage of knowledge," on quantitative findings (1956, p. 441).

2. Verbal TAT (VTAT). Like most clinicians, Sargent has found that the scoring methods used in conjunction with one projective device may profitably be applied to another. Methods used in conjunction with the TAT, for example, were said to be "especially applicable" (Sargent, 1953, p. 21) to the Insight Test. By the same token, Insight Test scoring method has been applied to TAT protocols (Sargent, 1953).

As may be inferred, the two methods have much in common. Indeed, a verbal form of the TAT has been in use with the blind since approximately 1952.[2] This use of a VTAT is by Sammie K. Rankin, and is based upon her modifications of the TAT descriptions in Murray's Manual (1943). An examination of Rankin's VTAT[3] and descriptions given by Murray reveals many interesting changes. In view of the use of Murray's descriptions in preliminary investigations of another development of a VTAT for the blind, to be discussed in turn, two of Murray's TAT descriptions and Rankin's VTAT stimuli are presented for comparison. First, two similar descriptions based upon Card 12BG are compared, next two dissimilar verbal depictions, based upon Card 19, are contrasted. To make comparison and identification easier Murray's (M) description is given first followed by Rankin's (R) in each case.

(M) 12BG. A row boat is drawn up on the bank of a woodland stream. There are no human figures in the picture.

(R) 12BG. A row boat has been drawn up on the wooded bank of a stream. There are no people in this scene.

(M) 19. A weird picture of cloud formations overhanging a snow-covered cabin in the country.

(R) 19. This is an abstract picture. Everything is blurred in outline as if with snow, and wind is indicated by jagged projections on several blurs; these projections stream in the same direction. There is a mound of white with two, lighted squarish spots which might be windows or doors. There are two more lighted squares high above the first two. There are blobs and splotches of gray at the top of the picture.

Rankin uses standard instructions for her VTAT, which she has found to be "an excellent projective technique." She prefers a content analysis approach although she occasionally has used that of formal scoring.[3] Further, she has "observed no significant difference between the stories of blind persons and sighted persons even when the responses from sighted persons have been given to the picture instead of the verbalization."[4] These observations, however, are based largely on impressions or inspection rather than on statistical evaluation.

Independently of Rankin, though at a later date, Lebo (1955) noted that disliked TAT pictures were usually the same cards whose descriptions in Murray's Manual (1943) contained disquieting elements. This observation suggested the possibility that the original description of the TAT cards contained approximately the same stimulus value as did the cards themselves.

Lebo and Harrigan (1957) later compared TAT and VTAT presentations of stimuli. It was hypothesized that if card descriptions were read to subjects the same responses might be

[2] Sammie K. Rankin, personal communication, April 9, 1958.

[3] Sammie K. Rankin, personal communication, May 1, 1958.

[4] Sammie K. Rankin, personal communication, June 12, 1958.

elicited as from the usual TAT administration. To compare the value of such stories to traditional TAT protocols they used various objective measures including word count, idea count, emotional tone of stories and outcomes, response level, dynamic content, perceptual range, common themes, and normative data. All of these devices had been successfully employed in the traditional TAT literature.

It was found that the verbal descriptions of TAT pictures evoked responses comparable to those of the TAT itself. The substitution of verbal descriptions for visual plates was apparently justified, at least for experimental purposes.

A later study by Lebo and Sherry (1959) contrasted a VTAT read to subjects with a VTAT read by subjects. Again, Murray's unaltered descriptions were used. Differences between these two methods of VTAT presentation were largely nonsignificant according to the objective methods of comparison listed previously. It was emphasized, however, that the TAT appeared to possess stimulus properties not evident in Murray's descriptions. Rankin's VTAT apparently was developed to close such a gap.

While Lebo and his coworkers have not yet used a VTAT on blind subjects they have been concerned with such usage ultimately. It was felt, however, that individual comparisons of protocol content to TAT plates and descriptions were necessary before developing a substitute VTAT. The more the VTAT parallels the TAT the easier it should be to use TAT norms in VTAT interpretation. Research along these lines is underway and a preliminary scoring manual (Lebo, 1959a) with the presentation and analysis of two 20-item VTAT's has been prepared. In the meantime, material of research interest and clinical value in general has been presented (Lebo, 1959b).

3. Sentence Completion. Like the TAT, the Sentence Completion test has been used extensively with sighted subjects before being applied to the blind. The Incomplete Sentence Blank (ISB) has been recommended for use (Bauman & Hayes, 1950; Bean, 1957; Morris, 1950) and actually used (Dean, 1957) with the blind. The ISB is a semi-structured technique which confronts the blind patient with clearly spoken (word or phrase) sentence stems. He is instructed to complete these stems in a manner expressive of his real feelings. Some extremely ambiguous items such as "I.....," and "Sometimes.......," are included.

Originally devised as a military screening test (Rotter & Willerman, 1947), the ISB still consists of 40 items (Rotter, 1950). As with the Insight Test, experienced psychologists are urged to devise special items for their purposes. Thus, Rotter and Rafferty (1950) have changed several items to develop an ISB College Form. By means of a few additional changes this form can be converted into one for nonschool adults or high school students. Additional changes would seem to make such forms easily adaptable to blind persons of various age and cultural groups.

The entire test protocol can be obtained in about 20 minutes on a single sheet of paper. It can be scored by classifying completions into categories such as conflict responses, positive or healthy responses, and neutral responses. The latter are completions not falling into either of the previous categories. Humorous and avoidance responses such as "Most girls are females" are regarded as neutral statements. Numerical values are assigned to indicate the nature of the response group and the strength of the statement. Conflict responses are given positive values while positive statements receive negative scores. Thus, the higher the score the greater the maladjustment. Scoring methods and examples are available in the Manual (Rotter & Rafferty, 1950).

Rotter and Rafferty (1950) have reported a cutting score which identifies 75-80 per cent of maladjusted subjects. Dean (1957) found that 54 blind persons scored higher than

Rotter and Rafferty's norms for a well adjusted group and for college freshmen but lower than maladjusted groups. Although the chief recommendations of the ISB are its objectivity and its lack of dependence upon unusual clinical skill--relatively untrained persons can score it reliably--Dean concluded that, the "Rotter ISB...value with the blind probably resides in qualitative rather than quantitative evaluations" (1957, p. 176).

Another form of sentence completion test proposed for use with blind persons (Morris, 1950) is that of Stein (1947). This test consists of two parts, each of which contains 50 complete sentences. A variety of areas important in the evaluation of personality are covered. They include: family, past experience, drives, inner states, goals, cathexes, energy level, time perspective, reactions to others, and reactions to frustration. Sentence stems are of two types, i.e., eferences to third parties ("Mike's fondest ambition ....") and to personal items ("I try hard...."). Responses are analyzed by underlining significant completions. Hence, the interpretive skill of the clinician is emphasized strongly. The test has, understandably, been characterized as "descriptive but not evaluative" (Symonds, 1947, p. 321).

McAndrew (1950) used a sentence completion test with 25 blind, 25 deaf, and 25 normal children matched for age and intelligence. He found the blind group to be the most rigid of the three.

An interesting variation in the presentation of sentence completion material is a Braille adaptation (Brieland, 1950). This version is discussed more fully in the section of the present paper on three dimensional tests.

4. Word Association. The auditory projective tests treated thus far all have the use of unambiguous words in common. Starting with techniques employing complete statements the survey has progressed through briefer stimuli to the use of single words as stimuli.

Word association is one of the oldest formal free association techniques. It has been recommended for use with the blind (Bean, 1957; Morris, 1950) but a search of the literature has been unsuccessful in providing reports of such use. One of the first to use this method was Jung (1918). His list of 100 words, chosen to represent areas of emotional disturbance, is still among those frequently cited. A list frequently employed is that of Kent and Rosanoff (Rosanoff, 1938). Disturbed associations to their 100 neautral words, are detected by unusual content.

While word association tests are easily administered, normative responses have varied so with culture, region, intelligence, and time that they have not proven generally repretative. The most recent freauency tables are those of Tresselt and Leeds (1953a, 1953b). For particular research problems it would seem to be advisable to prepare special words. Consequently, norms for such words will also have to be established.

C. AUDITORY PROJECTIVE TESTS: STIMULI RECORDED

Interest in vague auditory stimuli as projective, or imaginative media can be traced to da Vinci (Richter, 1939). He mentioned the confused noises made by bells in which words or names might be imagined. The jangle of bells and the confused or disguised sounds of several auditory projective tests are not too unlike. Auditory projective devices requiring recorded stimuli may be arranged from those making use of clearly audible words, through tests employing inaudible, disguised, or unreal speech and sound effects, to a test employing neither speech nor sound effects.

1. Azzageddi Test (Azz Test). The peculiar title of this technique comes from Melville's *Mardi and a Voyage Thither* (1922). In that story a devil, named Azzageddi, was blamed for

causing the speech of one of the characters to become confused and incoherent. The name of the test, in addition to being appropriate, has another advantage in that the purpose of the test is not inherent in its title. To disguise further its purpose, subjects are informed that it measures "intuitive intelligence" (Davids, 1956, p.416).

The Azz Test (Davids & Murray, 1955) was designed to measure eight specific emotions or feelings. Believed to be important components of personality structure, these dispositions are: optimism, trust, sociocentricity, pessimism, distrust, anxiety, resentment, and egocentricity. For each disposition eight sentences and six short phrases were recorded. Stimulus material for each of the feelings also contains isolated statements and phrases associated with other dispositions. For example, recorded material for the feeling of optimism contains words associated with other dispositions. Four unrelated statements in the passage are intended to represent trust, distrust, sociocentricity, and egocentricity. Six dispositions are also represented in it by a single word or a short phrase.

The Azz Test recorded stimulus for evaluating optimism is: Beware of sly men, laden with malice, breeders of dirty lies, and smearers of character. Boiling with rage. Opportunities for happiness are unlimited. Disbelieve. It is not what we take up for ourselves, but what we give up for others that truly makes us rich. Trustworthy men. Have confidence in yourself and in your future. Life is a great goblet of glorious possibilities, brimming over with enough delight to make us giddy. Equality for all. Never loose faith in your fellow men. Desire for power. Let neither sorrow nor disappointment bend you down to earth. Peril upon peril. People love themselves above all others (Davids & Murray, 1955, p. 550).

By themselves the aforementioned statements are coherent and unambiguous but when combined the resultant passage is considerably confused. Ambiguity and incoherence is provided by the nature of the content rather than by inaudibility or masking.

Subjects are to remember as many ideas as possible while listening to each of the one-minute passages. A three-minute interval follows each passage during which time the subject is required to write or tell as many ideas, phrases, and statements that he may recall.

Relations between selective auditory memories of the passage above and subjects' personalities were presented by Davids and Murray (1955). Understandably, they feel the procedure may prove useful in studying the mental processes of the blind. Insofar as the literature is concerned this application does not yet seem to have been made. The originators have, however, compared scores for five negative dispositions, i.e., egocentricity, distrust, pessimism, anxiety, and resentment, on the Azz Test with a tape recorded word association test and a sentence completion test. Rho's were .55 and .54 respectively, both sitnificant at the .01 level of confidence.

2. Auditory Sound Association Technique. Wilmer and Husni's (1952, 1953) auditory projective test consists of 21 sound series. These evocative noises, including words, were chosen, from 117 originally tested, because they produced greater responses, more varied contents, and also because they were rejected for more significant reasons (Wilmer, 1951). They are available for research purposes on two 12-inch records (Briggs, Gaede, & Wilmer, 1956). Subjects are told to associate meanings to the sounds and to represent aloud the first thing that comes to mind. If subjects wish they may make up stories about the sounds.

Some of the sounds, with the number of their sequence, are:

8. Laughter and man and woman conversing. A. "Where did that damn thing come from?" B. "What thing?" A. "Mother said you can't always get what you want in this world, sister." B. "What did you expect?" A. "Where is Dad? Where did Dad go?"

10. Man and woman arguing (man speaks in anger). Man: "Now what did you do all that for today!" (Mumbling answer). "Huh?" (Mumbling answer). "You know what I'm talking about!" (Mumbling answer).
1. Train leaving station, crowd, depot noises.
21. Train bells, switch engine, loud bang, voices.
15. Groaning, rubbing, kissing (human).
11. Music and water sounds, ending with splash like fish in water or man drowning.
18. Drill.

Tests of this nature have been recommended for use with the blind (Allen, 1958) and 21 blind children have been compared with other disabled groups (Wilmer & Husni, 1953). The blind subjects mentioned elements of violence, death, and struggle more frequently than tuberc ulosis patients, schizophrenic patients, and amputees. The blind children also detected background noises more keenly but tended to reject other components of sounds when their verbalization was fixed on danger elements. Their own handicap was reflected in comments about walking, unseen danger, and warning signals. Individual responses were presented and analyzed.

3. Auditory Apperception Test. Stone (1950) has developed an Auditory Apperception Test which has been recommended for use with the blind (Allen, 1958; Stone, 1950). This test also consists of recorded words and sounds of various types. Like the Auditory Sound Association Technique, episodes in dialogue form are also used. Because of the inclusion of discernible phrases the test is considered among those utilizing words.

The set of 10 records, one of the few recorded auditory projective devices available commercially (Stone, 1953), presents three sounds in each of 10 "sound situations." Various combinations of the following types of sound occur: (a) dramatic episodes, including a single dialogue such as: "You ready Joe?" "Yeah, I'm ready." "You ready Fella?" "I'm---not sure." "Come on, let's go!" (b) non-verbal human sounds (crying, laughing); (c) animal sounds (bird calls); (d) nature sounds (thunder, fire); and (e) mechanical sounds (pounding, bells).

After hearing each group of three sounds, the subject makes up a story, much like the TAT requirements, telling what has caused the sounds, what is happening, and the outcome. A record form, making a TAT-like analysis according to theme, character, and outcome easier, is available.

4. Auditory Projective Technique (APT) Braverman and Chevigny (1955), with the help of the American Foundation for the Blind, have advanced a test believed applicable to persons with severe visual defects. The APT consists of two records with short, spoken sequences and sound effects of unstructured content. The sequences are intended to be auditory depictions of feelings and objects. The first record consists of seven conversations between people of different sexes and ages. Some of the sequences consist of a quarrel, a love scene, and and an old couple. Although these conversations have an emotional content they are ambiguous as to word content because they are in a nonsense language. Six subsequent sequences are English language versions of several earlier sounds. The obverse of the second record consists of brief sound effects designed to portray scenes, i.e., storm, escaping criminal, suicide, sea rescue, and snooper.

In addition to being instructed to use imagination, subjects are also to make up a TAT type of story, telling what is going on, what led up to it, and eventual outcome.

Both the APT and the TAT were administered to 40 patients, excluding disturbed psychotics. Information obtained from the APT was comparable to that secured from the TAT when a need-press type of analysis was made of the protocols. The originators, however, point out that while their test is out of the experimental stage it has not been standardized. APT records are available for research workers (Braverman & Chevigny, 1955).

5. Tautophone (Verbal Summator). The Verbal Summator, introduced by Skinner (1936) is one of the oldest of recorded, free association tests. The Verbal Summator is made up of unfamiliar speech samples. While employing the Summator to investigate hypotheses concerned with the development of speech, Skinner drew an analogy between that device and projective techniques. Shakow and Rosenzweig (1940), stressing projective possibilities, renamed the test as the Tautophone. They used only two of Skinner's records consisting of various vowel combinations, each of which was repeated 10 times. (Tautophone is a combination of the Greek to auto and phone, meaning the same sound.) Some of these sounds are presented below. Long vowels are indicated by capital letters, short vowels by small letters, the vocalization uh by: "I'ah, 'a'A, ahO''', and eah''' (Grings, 1942,p. 541).

Subjects are informed that the recorded voice is unclear and that it will be necessary to listen carefully. As soon as a subject has some inkling of what is being said he is to tell the examiner. Thus, to Eah''', one subject's interpretation was "my knees are apart" while that of another was "eu as in Hindu" (Shakow & Rosenweig, 1940).

The test lasts from 20 to 30 minutes. It has been suggested that two persons administer the Tautophone, one to operate the phonograph and record the number of stimulus repetitions preceding a response, the other to record responses and other pertinent information. Shakow and Rosenzweig (1940) have devised a method of scoring which considers such response factors as similarity to stimulus, English language nature, personal references, grammatical structure, i.e., interrogative, imperative, or declarative. They have also developed a series of 12 indices measuring such dispositions as suggestibility, self-reference, subjectivity, and perseveration. Perseveration, for example, may be determined by dividing the number of different words in the responses by the total number of words. The originators of these indices have pointed out similarities between Rorschach scoring and Tautophone evaluation methodology.

Trussell (1939) found the Verbal Summator discriminated between groups of normals and abnormals while Grings (1942) found differences among groups of psychotics. Despite such early usage, no reports were found indicating that such stimuli had as yet been applied to blind subjects. The test is applicable to such persons and has been so recommended (Allen, 1958; Morris, 1950).

6. Sound Apperception Test (SAT) Bean's SAT (1957) seems to be one of the few auditory apperceptive techniques which employs sound effects and no human vocalization. SAT material consists of recorded sounds ranging from ambiguous to semi-structured noises. Ordinary sounds were made ambiguous by distortion, i.e., by slowing their speed, reversing them in sequence, or reducing them in frequency.

The SAT is comprised of two parts, the first consists of 10 unstructured noises and the last of 16 semi-structured sounds. In responding to the first series of sounds subjects are asked to indicate of what they are reminded by the sound. The second series, however, requires subjects to tell what is happening, what led up to the event, and finally what the outcome might be. Special attention should be given to the thoughts and feelings of any people that might be included in the stories. Once again the influence of the TAT is apparent in the instructions.

One example of a sound series in the TAT like sequence are noises of a diesel train approaching and passing, galloping horses, and then swishing canoe paddles. Some responses to such stimuli describe a pleasant vacation trip, others picture an excaping criminal who jumps off the train, hides as a posse on horseback looks for him, and who finally swims away. These two patterns seem to be basic for the sound sequence. Many variations are said to occur, however.

Preliminary testing comprised approximately 200 persons. Of this number 35 were blind. Such subjects were found to take more interest in the stimuli than did the sighted and to give fuller elaborations. When the variables were quantitatively measured, however, few significant differences were found. Scoring has been standardized and interrater agreement seems stabilized around .73 to .76 (Bean, 1957). Scoring sheets, a manual of instructions, and the recorded stimuli are available.[5]

7. Musical Reveries Test. In addition to being relaxing, music can also serve as stimulation to expressive activities, and as a physical or emotional release of conflict (Ashford, 1955). Since the blind are believed to live generally under tension, music has been recommended as an excellent tool for such people (Korhonen, 1956).

A Musical Reverie Test, suggested for such use (Morris, 1950), is that of Kunze (1938). The test consists of listening to parts of classical compositions while the mind drifts. Subjects are to note their mental images and weave them into a plot or allegory. When the selection is completed an account of the reverie is rendered.

The records were: (a) Symphony No. 4 in F minor, by Tschaikowsky, which usually suggested fear, agitation, mental or physical struggle. (b) Don Juan, by Richard Strauss. The last part of the second movement brought to mind love scenes, sentimental or romantic settings. (c) Symphony No. 6 in B minor (Pathetique) by Tschaikowsky, last movement only. This record brought forth stories of tragedy, despair, and sometimes death. (d) Quintet in G minor, by Mozart, closing movement. This suggested happy, lighthearted, animated action. (e) Death and Transfiguration, by Richard Strauss commonly brought to mind feelings of reverence and solemnity, or ideas of regeneration. (f) Afternoon of a Faun, by Debussy, placid and slow-moving, seemed to facilitate reminiscence and philosophizing. "Other records were occasionally used if one kind of music seemed to be definitely more productive than the others" (Kunze, 1938, p. 551). Kunze reported further that although these selections brought about rather characteristic attitudes and images, their specific form was influenced by the subjects' past experiences.

Despite its early appearance, the present writers have been unable to locate any references to the use of this music test with the blind.

D. TACTILE PROJECTIVE TASKS: THREE DIMENSIONAL TESTS

It is often assumed that the blind acquire superiority in their sense of touch. (Even though Seashore and Ling (1918) reported that they were not more sensitive in sensory discrimination than seeing persons in fundamental capacities.) Hence, it is not surprising to find a variety of three-dimensional projective methods recommended or created for evaluating the personality of the blind. For discursive purposes these tests are arranged on an age-depth continuum. That is to say, the oldest and most truly three-dimensional tests are mentioned first.

1. Three-Dimensional Apperception Test (3-DAT). The 3-DAT aims to elicit the overt expression of subjects' interests, needs, goals, sentiments, and emotions (Twitchell-Allen,1952). Constructed by Twitchell-Allen (1948), it consists of 28 ambiguous plastic pieces ranging

from geometric to organic forms. Her thesis is that manipulation and dramatic use of objects reveals properties of the person not disclosed by verbalization. Indeed, a comparison of 3-DAT and the Rorschach results revealed that more concrete material concerning inner goals, interests, conflicts, and anxieties arose from the former (Twitchell-Allen, 1947).

Administration consists of three parts: (a) the psycho-dramatic test in which the subject selects one or more pieces and makes up a story about them. This procedure is repeated several times. (b) A naming test in which the subject is asked to name the objects. (c) An inquiry in which the subject must indicate the reasons for his assigned names. During this phase subject may also be asked to compose a story centered on each of the names assigned the various objects. Stories and gestures are recorded formally in a summary record. Analysis, however, is left to the examiner's discretion.

As might be suspected, the 3-DAT has been recommended for use with the blind (Bauman & Hayes, 1950; Morris, 1950). In addition, McAndrew (1950) used it with 25 blind, 25 deaf, and 25 normal children. He studied individual personalities with the 3-DAT and a sentence completion test and found that while both tests were applicable to the blind they must be interpreted cautiously.

Test materials and scoring forms are available commercially (Twitchell-Allen, 1948).

2. Avon Three-Dimensional Apperception Test. This is one of the few projective techniques developed exclusively by use with the unsighted. Interestingly enough it has been recommended for sighted subjects (Levine, 1950). It consists of figures made in various media, such as plaster or lead, to which subjects free associate. The objects may be named, used as stimuli for stories, or otherwise given meaning. The instructions are simply, "Just associate to the figures, tell everything that comes to your mind while your hands are moving over them." The set is not completed (Morris, 1950).

3. Kerman Cypress Knee Test (KCK). Like the preceding three-dimensional techniques is the KCK (Kerman, 1957). Once again subjects are instruected to describe (or name) each piece and are allowed to select some or all of the forms as characters or properties for a story.

KCK forms are rubber replicas of six cypress knees. Cypress knees are natural above ground growths from cypress tree roots. They are popular souvenirs of Florida because of the myriad ornamental, grotesque, and ambiguous shapes they assume.

Three testing situations make up the administration of the KCK: (a) The object choice section in which the subject ranks his preferences for the forms, on a like-dislike basis, and justifies his ranking. (b) The part called projective images in which the subject names and tells about the images perceived. (c) A story situation during which two plots are required. The first task is a free association to characters already perceived in the KCK. The subject is next asked to assign the roles of mother, father, and child to three of the objects and compose a story involving these assignments.

Analyses, based on Fairbairn's (1954) object-relation theory of personality, consists of determining the symbolic meaning of each form and in assessing subject's attitude towards them. As a result the subject may be categorized as schizoid, depressive, phobic, obsessional, hysterical, paranoid, delinquent, or organic. Further discussion of theoretical aspects and administration as well as analysis of the records of sighted subjects have been presented in detail (Kerman, 1957, in press (a), in press (b)).

Kerman's initial experience in testing six blind subjects and copies of two full protocols and analyses are available in pre-publication form.[6] He is convinced that the percepts gained by the blind subjects' tactual exploration were practically identical with those formed through visual inspection.

Qualified applicants may secure the test stimuli from the originator (Kerman, 1957).

4. Bas-Relief Projective Test. Harris (1947) has constructed a projective test for the blind using bas-relief forms of varying textures, shapes, and structures as stimuli. These forms were based upon a series of chance ink blots, without attempting to imitate the Rorschach (Harris, 1948). Harris' plates were neither all symmetrical nor unstructured. Three of the plates, resembling horses, were initiated to determine the threshold of recognition. The first, clearly structured, resembles a horse picture, the third, almost unstructured, is so disorganized as to resemble only slightly a horse, while the second is in the center of this continuum.

The plates are presented three times. For the first presentation subjects are asked to examine (tactually) the figures and tell what they mean. The second presentation seems like a Rorschach inquiry, i.e., the examiner seeks to understand the nature of the stimulus to which the subject responded, to form or texture, for example. On the final presentation the examiner tries to force implied responses into overt expressions.

The practicability of the Bas-Relief Projective Test has been demonstrated during several experiments with approximately 100 blind and 300 blindfolded, but sighted, subjects. Unfortunately, much of this work seemingly has gone unreported in the literature.

5. Braille Sentence Completion Test. Brieland (1950) gave a sentence completion test to 250 visually handicapped children who were matched with sighted controls. Thirty items con cerning social and home adjustment and family attitudes were presented in Braille or large print. Subjects wrote their answers.

The blind or partially sighted persons showed increased emotionality, excessive anxiety about family relationships, and more dissatisfaction with school achievement.

E. TACTILE PROJECTIVE TASKS: CREATIVE AND EXPRESSIVE

The projective techniques discussed in this section involved something the subject has made, i.e., sculptured, painted, drawn, or written. Since these procedures are more unstructured than any of those mentioned previously, it is not unexpected to find that methods of interpretation are similarly ambiguous and depend to a greater extent upon clinical intuition and acumen than many of the previous tests.

1. Plastic Material. In his listing of projective techniques of value in testing the visually handicapped, Morris (1950) called attention to projective techniques frequently employed with the sighted. Quite properly he included clay modeling in the enumeration. However, in saying that, "practically all of them are unsuited for use with the blind, vision being an important factor" (1950, p. 117) Morris seems to exclude plastic material from consideration in revealing the personality dynamics of the blind. Bauman and Hayes (1950), following their one-sentence treatment of projective techniques, cite an article (Bender & Woltman, 1937) on plastic material. Such citation, to the present writers, connotes a recommendation.

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[6] E.F. Kerman, personal communication, May 26, 1958. Since the present review was accepted for publication one of these records has been published. See footnote No. 1 for bibliographic information.

Bender and Woltmann (1937), while not working with blind subjects, present much theoretical, explanatory, and interpretative material of value in reflecting personality dynamics. This diagnostic aspect, unfortunately, has not been one of Lowenfeld's (1939) interests in his published studies of a large number of the clay models, drawings, and paintings made by blind and partially sighted children and adults. He has been concerned with aspects of Creative and Mental Growth (1955) rather than with the entire personality. Nonetheless, his "discussion of these factors and his exposition of them...is highly stimulating and should be read by all who are interested...in projective theory..." (Goodenough & Harris, 1950, p. 411).

2. Finger Painting and Handwriting. The first medium has been especially recommended (Kadis 1952) and used (Napoli & Harris, 1948) with the blind because of the plasticity of the material. It allows for freedom in manipulation while the picture itself is a socially acceptable projection of needs. According to Napoli and Harris (1948) the very motion of smearing is relaxing and there is no social structuralization to prevent expression.

Work with 25 blind or partially sighted subjects revealed that their motions were not limited by their handicap but by their emotional set instead. The texture of the pictures was similar to those produced by sighted persons. Composition, balance, and perspective were also well represented (Napoli & Harris, 1948).

It is interesting to note that Wolff (1948, pp. 156-158) in studying the handwriting of the blind came to much the same conclusion.

The methods of administration and interpretation of finger painting vary according to the examiner. Subjects may be asked to make up a story around their pictorial construction. A simple, objective 12-point scale differentiating between nonpsychotic, manic depressed schizophrenic, and organic groups has been developed (Lehmann & Risquez, 1953), but has not yet been tested on blind persons.

F. DISCUSSION

Like the majority of projective techniques, those treated in the present paper are largely in an experimental stage and depend in great measure upon clinical skill rather than routine scoring. In several cases studies concerned with validity and reliability have been performed and objective scoring schemes advanced. However, because examiners of the blind are frequently urged to alter tests to suit particular needs, reliability and validity data, unless of particular interest, were not treated in detail. The reliability of one form of a test should be established anew each time any segment of that test is modified. It is regrettable that this precaution is undertaken only rarely, even with one of the most frequently used and frequently altered objective tests (Lebo, Noblin, & Toal, 1957).

This survey of tests considered effective by investigators who have indicated their recommendation in print was concerned with devices stimulating projectivity or creativity (the terms are almost inseparable to the present writers) through senses other than sight. The avenues of perception which remain are hearing, touch, smell, and taste. Little traffic has been reported on the last two avenues. None of what has been published is concerned with the blind.

Several of the auditory projective tests requiring recorded stimuli have names so similar as to be confusing: Auditory Sound Association Technique, Auditory Projective Technique, Auditory Apperception Test, and Sound Apperception Test. The name Auditory Sound Association Technique, used by the present writers, comes from the title of the first publication describing this test (Wilmer,1951). This designation was not employed

consistently in other articles by Wilmer and Husni (1952, 1953). Since the originator has not yet named his device its name may be altered easily. The Sound Apperception Test (Bean, 1957) also seems to be a tentative title. Names of these two tests, then, may be altered without difficulty.

To prevent increasing confusion, as more auditory projective devices appear, the present writers suggest a uniform policy in regard to designation. Since the tests above have many similarities and equal evanescence a subspecies-species designation would seem to be applicable. The names of the senior investigator should precede a more general, abbreviated indication of the auditory projective nature of the test. Thus, the Auditory Sound Association Test becomes Wilmer's APT, and the Sound Apperception Test becomes Bean's APT. This usage is consonant with that employed to differentiate Rankin's VTAT stimuli from Murray's descriptions and may be extended to embrace the established 3-DAT designation. Unusual identifications such as the Azzageddi Test probably will cause no difficulties, unless the test becomes popular.

The 1947 review of the literature (Morris, 1950) did not encounter this difficulty with names. It described only the Tautophone and the Musical Reverie Test. A variety of APT's has been introduced since then. The literature reporting these new arrivals is much alike. They usually begin by reviewing publications on previous APT's. Immediately complaints about the lack of norms, standardization, and clinical employment follows. However, instead of eliminating these deficiencies from older APT's, the authors present a new one with seeming ease. Indeed, one APT was done as a hobby and has since been abandoned by its originator.[7] Raskin and Weller (1953) cite two master's theses (Biggs, 1952; Lax, 1953) whose authors developed their own auditory projective tests instead of working with APT's already established.

It is to be hoped that the present paper will bring this situation, as well as awareness of older projective devices, to the attention of psychologists so that earlier tests may be explored before newer ones are thrust upon us. Like the broom of the sorcerer's apprentice, the problems are being multiplied instead of satisfied.

The situation strikes the present writers as resembling that of 15 years ago when many psychologists tried to gain fame by developing a new projective device, or earlier when many physicians sought immortality by endeavoring to describe and name a new phobia. Today the trend seems to be the offering of a new APT suitable for use with the blind.

A comparative investigation should be made of all recorded APT's and the best one, or better parts of several, designated by scientific methods rather than new APT's designed by intuitive cerebration.

Such an investigation should also consider the occurrence of similar sounds in different APT's. For example, train noises and the sound of footsteps are both parts of the stimuli of the Auditory Sound Association Technique, the Sound Apperception Test, and the Auditory Apperception Test (or Wilmer's APT, Bean's APT, and Stone's APT). Seven additional, similar types of sounds occur in both Wilmer's and Stone's APT's. The question of whether such stimuli are duplicates or have different meanings in their respective contexts should be settled. Such factors as the influence of background noises on foreground sounds, and the effect of sequence in the presentation of several sounds should all be investigated before additional APT's are born and then abandoned like unwanted children.

The present writers would suggest that the significance of single sounds be examined first. After that has been determined combinations and sequences could be systematically evaluated. Sound types repeated in two or more APT's might first be investigated. In addition to footsteps, train sounds, and water noises (found in at least three APT's), the list would include groaning, crying, laughing, quarreling, singing, crowd sounds, bird calls, and machine noises. In this manner a sound experimental foundation for APT's would be secured.

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[7] D. R. Stone, personal communication, June 27, 1958.

A study by Stone might be of especial importance here. For he compared the responses of 220 college students who listened to a record of a bird chirping, a train coming from a distance which comes closer until a crash is heard, and a trumpet fanfare, to the protocols of 74 students who were asked to imagine the sounds which were verbally described to them. It was found that "responses to imagined sounds were either similar to the recorded version, or included them plus additional elaboration. The use of imaginary (verbally described) sounds seems as productive, though less structured than the recorded stimuli" (Stone, 1955, p. 254).

These results indicate that sentences may be substituted for complex sound series and suggest that single sounds may be replaced by single words. If such an hypothesis is tenable then a word association test might indicate responses to imagined unitary sounds. Sounds in brief combination might have their significance determined in the manner of a sentence completion test and noises in more involved arrangements or in descriptive situations might have their interrelationships and sequence determined by Insight Test or VTAT techniques. Since both visual and vocal presentation of the latter stimuli were found to be alike (Lebo, 1959; Sargent, 1956) massive preliminary data might be collected in group situations by means of mimeographed stimuli and written responses.

The apparent ingenuity of such a proposal will not serve for all APT stimuli. How verbally describe some of these unstructured noises of Bean's APT? Nor could unstructured stimuli from 3-DAT projective tests be verbalized for the matter.

The 3-DAT type of test also shows a tendency towards duplication with little use of older and apparently equally good devices. A comparison of these examinations to determine the best one or the best features of several would certainly be in order. Preliminary investigations of such independent features as texture, size, shape, weight, temperature and their influences on responses alone and in combination should be undertaken.

From such a beginning an APT or 3-DAT with the nuances of a Rorschach Psychodiagnostic might eventuate. Scoring methods for the new test may first have to free themselves from an overdependence on TAT methodology. Shakow and Rosenzweig (1940) have developed an original scoring system for the Tautophone that is closely related to that test. They were influenced, however, by the Rorschach ink blot scoring system. One well based APT and 3-DAT should attract a variety of research efforts and empirical accretions which may serve to produce original and subtle scoring procedures over time, unless a giant such as Rorschach appears.

Before embarking upon the formulation of one perfect APT or 3-DAT the necessity of different types of projective devices in various sensory modalities should be determined. If a VTAT in vocal or braille form is as effective with blind subjects as a TAT with sighted, then elaborate sound tracks and cumbersome three-dimensional figures may not be needed. Nor may it be advisable to approach various sensory doors with unusual devices that ultimately rely on TAT scoring. These tests should all be compared to VTAT findings. If the same kind of information is elicited, less convenient tests might be eliminated. If qualitative differences in APT's and 3-DAT's are smothered by quantitative TAT type approaches then this familiar, but perhaps inappropriate, scoring procedure should be eschewed for such tests.

Investigations comparing the effectiveness of several personality measurements appealing to different sense organs are few in number and usually impressionistic in nature. Thus, Kerman[8] stated that percepts gained by tactual exploration of cypress knees by the blind

[8] E.F. Kerman, personal communication, May 26, 1958.

were practically identical with those found through visual inspection. The superiority or inferiority of the KCK in relation to other methods has not been established. Twitchell-Allen (1947) found the 3-DAT to be more informative in certain aspects of personality than the Rorschach test when results were compared in the same individual. Information obtained from the APT was found to be "at least comparable to that obtained from the TAT" (Braverman & Chevigny, 1955). The scant results are, with the exception of Twitchell-Allen's discouraging. A criterion measure should be established (the present writers would like to propose a VTAT for this position) and all other tests measured against it. If they do not secure more information, or a different kind of information, they may be shelved for special usage.

This special usefulness depends upon their being rarely encountered. Because of this aspect they may serve as projective reevaluators of test wise subjects or institutional habitues. Even such patients will probably not be familiar with many of the tests herein described and may find themselves responding, once again, to unstructured stimuli.

G. SUMMARY

Projective stimuli recommended or used as suitable evaluative procedures with blind persons have been presented. Because many of them are little known they were discussed in detail. While the number of such methods is still limited (approximately 20 were found in the literature) noticeable development has occurred. They seem to be increasing in a dangerous manner. That is, instead of older tests being investigated newer ones are being devised.

Because of similarities of names in many such devices a standardized titling procedure was suggested. Because of similarities of content a fundamental research program was suggested. It was indicated that much of the experimentation on the dynamic meaning of sound stimuli could justifiably be conducted by associations to written words or sentences. It was also pointed out that possible nuances of approach may be eliminated by dependence upon a TAT scoring system. Devices that were developed because they were different would seem to merit original scoring procedures.

It was suggested that one immediate use for lesser known auditory or three-dimensional projective tests would be the diagnosis of test wise, slighted clients.

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V

THE DEVELOPMENT AND EMPLOYMENT OF VTAT's OR PICTURELESS TAT's

by

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A. INTRODUCTION

Odd as it may seem at first glance, a pictureless TAT offers several advantages. In the first place, a pictureless or verbal Thematic Apperception Test (VTAT) would seem to be more ambiguous than graphic representation. In an effort to cause the pictorial stimuli to retreat from consciousness and the underlying personality to be revealed more clearly Murray (1951) suggested that subjects examine a picture for 20 seconds or so and then lay it aside prior to responding. While Bellak (1952) described a method in which patients were to be shown a picture, then instructed to look at the ceiling and project the picture just seen onto it in imagination. Subjects were asked to describe this picture and tell the traditional story about it. Verbal descriptions of the TAT card presented visually (ViTAT) for subjects to read, or presented vocally (VoTAT) by being read to subjects, would eliminate contact with the cards and require subjects to construct mentally their own pictures from the word stimuli. A VTAT would seem to be the most ambiguous of TAT's insofar as stimulus ambiguity is concerned.

In forcing the client to rely more upon himself and less upon the stimuli the evasiveness of card description would also be eliminated. Subjects might read ViTAT stimuli aloud or speak VoTAT words aloud for clarity. Such performance, however, obviously would be a repetition and not an unskilled avoidance of a response.

Other important uses of a VTAT would be in group testing where the stimuli could be administered in recorded (VoTAT) or printed (ViTAT) form. Massive amounts of normative data, worthy of machine tabulation, could be collected easily. Such material has begun to appear recently in small quantities due to the difficulties inherent in several methods of administering group TAT's, whereas, the VTAT seems designed for large scale uses. Group use of a VTAT among different socioeconomic and age levels might quickly and easily establish standardization data of importance.

Intracultural comparison would be simplified as well. It seems easier to translate VTAT stimuli into appropriate words than to have TAT pictures redrawn in conformity with surroundings. For example, suitable words for TAT card 12 BG, "A row boat is drawn up on the bank of a wookland stream," are probably more readily available than suitable pictures for most cultures. Local flora are more easily and correctly imagined than depicted.

Projective testing with the blind could be advanced through the use of a VoTAT. While the number of suitable evaluative procedures for blind persons is increasing, there is a tendency to validate such new techniques by means of clinical impression rather than by comparison with older methods. Also, several such new methods are unsuitable for sighted persons or have no history of such application. VoTAT's would serve admirably as a standard for comparison. The more closely the VTAT resembled the TAT the more closely could the responses of the blind be compared with TAT norms and the more closely could other projective techniques developed for use with the blind be contrasted for effectiveness with an established personality examination. This matter has been discussed further by Lebo and Bruce (1960).

B. RANKIN'S VTAT

Information about the availability of the TAT for use with the sighted first appeared in 1935 (Morgan and Murray). It has been used in verbal form with the blind since 1952.[1] This use of the VTAT is by Rankin who is, herself, blind.[2] It is based upon her modifications of the TAT descriptions in Murray's Manual (Murray, 1943).

An examination of Rankin's VTAT[3] and the descriptions given by Murray reveal many differences. In view of the use of Murray's descriptions in the preliminary investigations of another development, by the present writer and his co-workers, both Murray's TAT descriptions and Rankin's VTAT stimuli are presented for comparison. To make comparison easier Murray's description is given first, followed by Rankin's. To make identification easier Murray's description are preceded by an M and Rankin's stimuli by an R.

C. MURRAY'S VTAT AND RANKIN'S VTAT

M 1. A young boy is contemplating a violin which rests on a table in front of him.
R 1. A boy is sitting at a table on which there is a violin and some papers which could be music.
M 2. Country scene: in the foreground is a young woman with books in her hand; in the background a man is working in the fields and an older woman is looking on.
R 2. This is a farm scene. There is a muscular man plowing with a team. In the foreground, there are two women. One appears to be pregnant. The other appears to be younger and has some books on her arm. The women are not looking at each other.
M3BM. On the floor against a couch is the huddled form of a boy with his head bowed on his right arm. Beside him on the floor is a revolver.
R3BM. Here is a figure collapsed in front of a cushioned bench. The figure's head rests on the bench; an arm circles the head. The other arm hangs off the edge of the seat, and an object which appears to be a gun lies on the ground nearby.
M3GF. A young woman is standing with downcast head, her face covered with her right hand. Her left arm is stretched forward against a wooden door.
R3GF. A woman with drooping head is standing in a doorway; there is darkness behind her. Her face is partly covered by one hand. The other arm is outstretched along a wooden door frame.
M 4. A woman is clutching the shoulders of a man whose face and body are averted as if he were trying to pull away from her.
R 4. A couple is standing in a doorway. The man appears to be leaving; the woman, to be pleading with him. There is a poster with a semi-nude figure on it on the wall beside the door.
M 5. A middle-aged woman is standing on the threshold of a half-opened door looking into a room.

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[1] Rankin, S.K. Personal communication. April 9, 1958.
[2] Maddox, J.K. Personal communication. February 5, 1958.
[3] Rankin, S.K. Personal communication. May 1, 1958.

R 5. Here is a well-furnished living-room. There are no people in the room, but there is a woman looking into the room through a door she has half-opened.
M6BM. A short elderly woman stands with her back turned to a tall young man. The latter is looking downward with a perplexed expression.
R6BM. A well-dressed man, looking toward the floor, is standing behind a woman who has her back toward him. She is holding a handkerchief in both hands and looking in the direction of some drapes which could decorate a window. The man is holding his hat in both hands.
M6GF. A young woman sitting on the edge of a sofa looks back over her shoulder at an older man with a pipe in his mouth who seems to be addressing her.
R6GF. On a sofa is seated a woman who is looking over her shoulder at a man who is smoking a pipe. They appear to be talking.
M7BM. A gray-haired man is looking at a younger man who is sullenly staring into space.
R7BM. Two men are sitting beside each other. One of them is looking at his companion who is looking straight before him.
M7GF. An older woman is sitting on a sofa close beside a girl, speaking or reading to her. The girl, who holds a doll in her lap, is looking away.
R7GF. A woman is seated on a sofa near a young girl who has a doll on her lap. The woman seems to be reading or talking to the girl. The girl is looking away from the woman.
M8BM. An adolescent boy looks straight out of the picture. The barrel of a rifle is visible at one side, and in the background is the dim scene of a surgical operation, like a reverie-image.
R8BM. A teen-age boy is day-dreaming; a gun leans against the wall near him. He pictures a scene in which a man is lying on a cot; two more men are beside the cot, and one of them has a knife in his hand.
M8GF. A young woman sits with her chin in her hand looking off into space.
R8GF. A woman, chin on hands, is sitting in a chair; she is absorbed in thought.
M9BM. Four men in overalls are lying on the grass taking it easy.
R9BM. Four roughly-dressed men are lying on the ground in attitudes of relaxation. They form a close group.
M9GF. A young woman with a magazine and a purse in her hand looks from behind a tree at another young woman in a party dress running along a beach.
R9GF. A woman with a purse and a magazine in her hand is looking from behind a tree at another young woman in a party dress running along a beach.
M 10. A young woman's head against a man's shoulder.
R 10. A man and a woman are embracing each other, but they are not looking into each other's faces or kissing.
M 11. A road skirting a deep chasm between high cliffs. On the road in the distance are obscure figures. Protruding from the rocky wall on one side is the long head and neck of a dragon.
R 11. Everything here is rather vague but there seems to be a stream with rock-strewn banks and a rough bridge. There is a procession of figures which might be either animal or human or both. There is an indistinct, branching path on the far side of the stream. There is also a cave in the background from the mouth of which protrudes the head and long neck of a prehistoric animal.
M12M. A young man is lying on a couch with his eyes closed. Leaning over him is the gaunt form of an elderly man, his hand stretched out above the face of the reclining figure.
R12M. A man with closed eyes is lying on a couch. An older man is kneeling with one knee on the edge of the couch; he lets one hand hang in a relaxed position just above the face of the man on the couch.
M12F. The portrait of a young woman. A weird old woman with a shawl over her head is grimacing in the background.

R12F. A woman sits absorbed in her thought while a weird, old woman hovers just behind her.
M12BG. A row boat is drawn up on the bank of a woodland stream. There are no human figures in the picture.
R12BG. A row boat has been drawn up on the wooded bank of a stream. There are no people in this scene.
M13MF. A young man is standing with downcast head buried in his arm. Behind him is the figure of a woman lying in bed.
R13MF. This is a poor room which is furnished with a table holding a lamp and some unopened books, a chair, and a low cot. Lying on the cot with her face averted, is a woman who is nude tobelow the breasts. In the foreground, stands a man with his arm held across his face in such a way as to cover his eyes.
M13B. A little boy is sitting on the doorstep of a log cabin.
R13B. A little boy is sitting on the doorstep of a log cabin. He is leaning in such a way that his thumbs are pressed against his lips.
M13G. A little girl is climbing a winding flight of stairs.
R13G. A little girl is climbing a winding stair. Her left hand is resting on the stair rail. She is wearing a cap.
M14. The silhouette of a man (or woman) against a bright window. The rest of the picture is totally black.
R14. A figure is silhouetted in a long window. The figure may be either male or female.
M15. A gaunt man with clenched hands is standing among gravestones.
R15. This scene is set in a cemetery: there are irregular rows of tombstones. There is an old-looking figure in a knee-length, black coat. Its hands are clenched and pointed toward the ground.
M16. Blank Card.
R16. You are to imagine a picture; you are to describe it and to make up a story about it just as you have done for the others.
M17BM. A naked man is clinging to a rope. He is in the act of climbing up or down.
R17BM. A nude, muscular man is holding on to a rope with his hands. He could also use his bare feet to hold with, but the rope is hanging free between his feet. Although neither end of the rope can be seen, it is obviously hanging from some over-head point of attachment.
M17GF. A bridge over water. A female figure leans over the railing. In the background are tall buildings and small figures of men.
R17GF. A woman is leaning over a bridge railing. In the background, there are some buildings, and some men can be seen as they load a boat.
M18BM. A man is clutched from behind by three hands. The figures of his antagonist are invisible.
R18BM. This is a hatless man in anunbuttoned overcoat. His face is turned to look in the direction from which he has come, but his eyes are closed. Although there are no other people to be seen, he is being held by three hands.
M18GF. A woman has her hands squeezed around the throat of another woman whom she appears to be pushing backwards across the banister of a stairway.
R18GF. Two women are on a stairway. The hands of one are holding the neck of shoulder of the other who is leaning backward against the railing. It is not clear whether one is supporting or attacking the other.
M19. A weird picture of cloud formations overhanging a snow-covered cabin in the country.
R19. This is an abstract picture. Everything is blurred in outline as if with snow, and wind is indicated by jagged projections on several blurs; these projections stream in the same direction. There is a mound of white with two, lighted, squarish spots which might be windows or doors. There are two more lighted squares high above the first two. There are blobs and splotches of gray at the top of the picture.
M20. The dimly illumined figure of a man (or woman) in the dead of night leaning against a lamp post.
R20. A figure in a hat and long coat is leaning against a post with light shining down

on it. The background is very obscure. There is an enclosure with low-growing plants behind the figure, and there are flecks of light which might be the lights of distant houses.

Rankin prefers a content analysis approach although she has used that of formal scoring occasionally. She has found her VTAT to be "an excellent projective technique."[4] Further, she has "observed no significant difference between the stories of blind persons and sighted persons even when the latter responses were made to the pictures instead of to the verbalization."[5] Here observations, however, are based on impression or inspection rather than on statistical evaluation.

Information about Rankin's VTAT has been briefly indicated previously.

D. LEBO'S USE OF MURRAY'S TAT DESCRIPTIONS

Independently, though at a later date, Lebo (1955) noted that the 10 TAT pictures which were most disliked because they contained affectively disturbing features were the same ones whose descriptions contained disquieting elements. This observation suggested the possibility that the original descriptions of the TAT cards contained approximately the same stimulus value as did the cards themselves.

This notion received additional support in an investigation of Newbigging's (1955) concerning London college students who rated 10 TAT cards on a happiness-sad scale. When the ranks assigned by the London students were correlated with the identical cards from Lebo's study a rho of .92 resulted. This comparison suggested that in different investigations with subjects from different lands the TAT cards were responded to with similar affect: Newbigging's sad cards were Lebo's disliked cards.

The accuracy of the hypothesized relationship between the stimulus value of the verbal descriptions of TAT cards and the plates themselves was later examined by Lebo and Harrigan (1957). They compared protocols given to TAT cards for college girls with the responses given by the same subjects to a vocal presentation of Murray's descriptions.

To compare the value of such stories to traditional TAT protocols they used various objective measures which included word count, idea count, emotional tone of stories and outcome, response level, dynamic content, perceptual range, common themes, and normative data. All of these devices have been successfully employed in the traditional TAT literature. Scoring manuals (Lebo, 1958) defining each of the above techniques with references, illustrations of use, and with scored protocols embracing two sets of stimuli for adult females, can be obtained from the present writer.

The TAT and VoTAT protocols were found to be similar according to the measures employed A later study by Lebo and Sherry (1959) contrasted ViTAT and VoTAT protocols of female college students using the scales and scoring methods listed above. A visual presentation of the descriptions yielded responses not unlike those given to a vocal presentation.

A study, now in process by Lebo and Naar, is examining the ViTAT and TAT responses of delinquent girls by means of transcriptions of tape recordings. Because of a high correlation between antisocial behavior, low-reading skill, and incapacity for self-expression (Salisbury, 1958) it will be interesting to observe whether the reading necessary for Murray's descriptions will reduce the similarities previously obtained for the TAT and VTAT responses of college girls. Should such a distinction not be the case it would suggest that the unchanged descriptions would have projective effectiveness even among poor readers. Preliminary examination of the data already collected from 10 institutionalized girls reveals no obvious differences.

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4 Rankin, S.K. Personal communication. May, 1958.
5 Rankin, S.K. Personal communication. June 12, 1958.

A comparison of Murray's VTAT with blind and sighted subjects is being carried out by Maddox[6] using Lebo's scoring manual for methodology. The statistics are in process now.

The comparability of results from TAT, VoTAT, and ViTAT is, perhaps, not entirely unanticipated. Stone compared the responses of college students who listened to recorded sounds to the protocols of subjects who imagined the sounds. He reported that: "The use of imaginary (verbally described) sounds seems as productive, though less structured than the recorded stimuli" (Stone, 1955, p. 254). Similarly, Sargent (1956) has remarked that responses to the Insight Test were not markedly influenced by a vocal or visual manner of presentation.

E. CONCLUSION

Both tradionally and empirically, then, a pictureless TAT administered visually or vocally by means of card descriptions would seem to be as diagnostically useful as the traditional TAT. Data obtained from some of the studies herein have already proven useful in answering questions raised about the diagnostic value of a pictureless TAT (Lebo, 1959). Further investigation if not the cautious use of VTAT's in clinical settings seems warranted.

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[6] Maddox, J.K. Personal communication April 16, 1959.

THE DEVELOPMENT OF TEN CHILDREN WITH BLINDNESS AS A RESULT OF RETROLENTAL FIBROPLASIA

A Four-Year Longitudinal Study

Aided in part by a grant from the American Foundation for the Blind

by

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It is well known that many children who are blind from birth or early infancy have normal intelligence, make adequate social adjustments and are successful in school.[1-3] These children ultimately lead constructive, independent, happy adult lives. There are successful teachers, chemists, physicists, doctors, psychologists, entertainers, and businessmen, as well as housewives, who are blind.[4]

The parent who is faced with the problem of rearing a blind infant has a difficult task The emotional reaction of most adults to the handicap of blindness is very great.[5,6] We, as a society are highly visually oriented, witness the growth of the television industry. Society does not readily accept a blind person. The parent of a blind infant has all of these feelings plus the feelings of being in some way responsible for the child's blindness. Such a parent , therefore, finds that he has to cope with these intense emotional feelings of his own before he can be effectively emotionally available to the infant. The blind infant, of course, needs the same emotional support and rich interplay of emotional life with his parents that all infants need for the development of a socially adequate personality. Furthermore, bereft of one important sense the blind child needs additional stimulation in other sensory areas rather than the social and sensory isolation he often encounters.

As any child progresses through infancy and childhood, parents are constantly looking for evidence that the child is doing well. The parents of most children make unconscious and conscious comparisons between the progress of behavior in their own child and the children they see around them, or have known in the past. They gain confidence as each milestone of development is successfully passed.

The parent of a handicapped infant, in this instance a blind infant, usually has had no experience with the development of such infants and children, and hence no way to judge successes or failures. These parents are afraid to rely on the usual cues on how to proceed with child rearing. A particular problem for them is how and when to urge the child to independent activities and self-help. Therefore, the parents turn to doctors and other professions for authoritative advice.

There are blind children who have serious neurological disorders, including mental de-

ficiency.[3] It is important for the parents to know when this is the case so that they do not drive themselves and their child to distraction seeking to achieve an impossible goal. On the other hand, sometimes a blind child appears seriously mentally retarded because of major emotional problems and after psychiatric help he evidences normal intellectual potential. The recognition of these children early is critical.

The problem of evaluating the developmental progress of the child with blindness as a result of retrolental fibroplasia is further complicated by the fact that this condition develops primarily in small, premature infants weighing less than 1,800gm. That the developmental progress of premature infants is delayed to the extent of the number of weeks of prematurity is known.[7] Unless this is understood, any premature infant may be judged as retarded in development in early infancy. However, it is also known that there is a higher incidence of neurological disorders and mental retardation in small, premature infants than among full-term infants.[8,9] All of these factors increase the urgency for adequate information about the development of blind premature infants to aid all who work with the blind children in making as accurate evaluations as possible.

Gesell[7] has stated that his child development norms for term infants can be applied to premature infants, if one corrects the infant's age by the number of weeks of prematurity. He further states that blind infants follow essentially the same developmental patterns as infants with vision. Thus, at least during the first year of life, the Gesell developmental test should be applicable to blind premature infants, allowing for the weeks of prematurity. In order to test this concept, in the fall of 1954 10 prematurely born infants of less than 1 year of age who were blind as the result of retrolental fibroplasia were tested, using the Gesell infant test.[7] These infants were considered by workers for the Field Service for Blind Preschool Children of the California School for the Blind to be normal insofar as they could determine from observations in the home. These infants were compared with 10 prematurely born infants with normal vision who were similarly tested and also 80 full-term infants. All of the infants were tested by the same examiner (A.H.P.). There was no statistical difference in the mean score for all three groups. It appeared that the statements made by Gesell were substantiated. These findings were reported [11] in 1955.

Although there is evidence that developmental quotients as obtained by infant tests do not correlate significantly with intelligence quotients obtained in later years by standard tests,[12-14] especially the Stanford-Binet test, these studies have generally included only children with average or higher intelligence. It is accepted by some that children with significant mental impairment can be detected by infant tests. Furthermore, this type of testing is more effective in detecting neurological disorders in infants than the standard neurological examination as applied to adults.[15]

All of the 10 prematurely born infants blind as the result of retrolental fibroplasia were judged to be developmentally and neurologically normal, except 1. This child (Case 8) was judged to be developmentally normal, but was found to have a major degree of hearing loss bilaterally and some ataxia as manifest by his poor balance and some hand tremor. Except for this case it seemed plausible to postulate that these blind children would continue to develop neurologically and mentally within a normal range throughout childhood. Even the child with the double handicap of blindness and deafness performed so well and in so many ways on developmental testing, it was felt that he, too, might continue to show evidence of normal mentality throughout childhood.

A four-year follow-up study of these blind children will be the subject of this article.

MATERIAL AND METHOD

The original control group of premature infants with vision who were tested in the first year of life with the Gesell test were retested between the ages of 3 and 6 years,

using the Vineland Social Maturity Scale and the Stanford-Binet Form L test. This testing was done by one of the examiners who had not seen them previously (C.F. or R.W.). Three children were originally tested as part of a routine program in an adoption agency before final adoption was accomplished. The follow-up testing was a voluntary courtesy of the adopting parents.

The 10 premature infants with blindness as a result of retrolental fibroplasia were originally referred for testing by the Field Service for Blind Preschool Children of California School for the Blind. These children are all under various private and clinic medical care. Thus, the follow-up studies have only been through the close relationship of the families to return for follow-up interviews, and not through a medical care program. There is, therefore, some lack of detail with regard to medical problems and physical development.

All of the children were seen between the ages of 18 months and 3 years of age by the original in a play situation for observation, and the parents were interviewed. A general evaluation of their progress was made on this basis. Although some attempt was made to use the Gesell test, it was found to be unstatisfactory in the hands of this tester in this age period with blind children.

Nine of the children were seen again for general observation and testing between the ages of 3 years and 5 years. The parents were also interviewed. The Vineland Social Maturity Scale and the Interim Hayes-Binet Test for the Blind[17] were used when applicable for this evaluation. This testing was done by the two examiners (C.F. and R.W.) who had not seen the children previously and did not know the results of the Gesell tests done in the first year of life or of the second play observation evaluation. One Child, Case 7, had moved to another city and was not available for testing and interviews after 18 months of age. However, through the courtesy of her parents and interested professional workers* in her new community, testing and observation evaluations were made available to us.

Electroencephalograms were done on six of the blind children at ages 3 to 5 years. One child (Case 10) was awake and not sedated. The others were sedated with chloral hydrate so that sleep tracings could be obtained. An electroencephalogram attempted on Case 2 was unsuccessful, owing to extreme hyperactivity even under heavy sedation with chloral hydrate.

Finally, biographical material was obtained on each child. This was obtained from the records of the workers of the Field Service for Blind Preschool Children, from our various interviews with the parents, and other agency, hospital, or medical records made available to us.

Developmental quotients or intelligence test scores of more than 80 were considered normal, recognizing 80-90 scores as dull normal according to definition.[16] Scores of less than 80 were accepted as indicating mental retardation but not necessarily mental deficiency. Mental retardation as used in this paper indicates less than normal functioning on any basis, whether through emotional interference, environmental deprivation, or inadequate mental potential.

A child is generally considered blind if the vision in his best eye corrected is less than 20/200. However, vision considerably less than this can be useful in moving about and in exploring new objects and places. Though all of the blind children were considered to have no vision when first seen, several developed useful vision of some degree. When this has occurred, this is indicated as useful vision. Those children with only vague regard for bright light were classified as having no vision.

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Table 1.—*Comparison of Early Infant Developmental Test Results and Later Intelligence Testing of the Prematurely Born Infants with Normal Vision*

			Original Developmental Examination		Retesting		
Case No.	Weeks of Prematurity	Birth Wt., Lb. — Oz.	Chronological Age in Weeks at Time of Test	Developmental Quotient	Chronological Age at Time of Retest	Stanford-Binet Score	Vineland Score
1	13	2	42	96	5 yr. 2 mo.	93	110
2	8	3 — 9	32	100	3 yr.	76	91
3	6	3 — 15	22	112	4 yr. 9 mo.	100	82
4	5	4 — 6	26	123		Not available	
5	4	4 — 11	18	107		Not available	
6	4	4 — 15	20	100	5 yr. 3 mo.	104	106
7	4	5	33	113		Not available	
8	4	5	28	108	3 yr. 2 mo.	102	
9	4	5 — 2	33	110	5 yr. 4 mo.	114	109
10	3	4 — 6	26	121	6 yr. 2 mo.	116	108

Table 3.—*Some Physical Characteristics of Ten Prematurely Born Children with Blindness as the Result of Retrolental Fibroplasia*

Case No.	Birth Wt.	Present Age (April, 1958)	Head Circ. (Present)	Neurological Signs	Electroencephalograms * at Present Age	Vision at Present
1	2 lb.	4 yr.	48 cm.	None	Mildly abnormal EEG because of increased prominence of slowing during light sleep — more than expected for age	None
2	2 lb. 3 oz.	4 yr. 4 mo.	49.5 cm.	None	Unsuccessful attempt due to activity of child even when heavily sedated	None
3	2 lb. 3 oz.	5 yr. 2 mo.		None	Normal	None
4	2 lb. 7 oz.	4 yr. 5 mo.	45 cm.	None	Normal	Right eye — none Left eye — useful vision
5	2 lb. 10 oz.	4 yr. 8 mo.		None		None
6	2 lb. 12 oz.	4 yr. 5 mo.	50 cm.	None	Mildly abnormal EEG with moderate to high potential slow 1-3 cps waves over the posterior scalp areas; more slow 1-3 cps activity than expected for her age	Right eye — 0 Left eye — useful vision
7	2 lb. 12 oz.	5 yr. 10 mo.				None
8	3 lb. 3 oz.	4 yr. 6 mo.	50 cm.	Deafness bilaterally; slight increase in knee jerks bilaterally	Normal	Left eye — none Right eye — useful vision
9	3 lb. 6 oz.	6 yr. 3 mo.	48 cm.	None		Left eye, Right eye } useful vision With correction using both eyes 10/70
10	3 lb. 8 oz.	4 yr.	48.5 cm.	None	Normal	None

* All electroencephalograms were interpreted by R. W. Walter, M. D., of the Department of Neurology, School of Medicine, University of California at Los Angeles.

Table 4.—*The Age of Successful Development of Four Self-Help Tasks by the Ten Prematurely Born Children Blind as the Result of Retrolental Fibroplasia*

Case No.	Present Age in Months (April, 1958)	Walking Without Support	Feeding Self With a Spoon	Talking in Sentences	Toilet Trained	Vision at Present
1	48	32 mo.	0	0 (Says a few words)	0	0 *
2	52	24 mo.	0	0 (Says a few words)	0	0
3	63	14 mo.	0	24 mo. (Has stopped talking at present)	0	0
4	53	27 mo.	30 mo.	30 mo.	36 mo.	Right eye — 0 Left eye — useful vision †
5	56	18 mo.	36 mo.	24 mo.	28 mo.	0
6	53	15 mo.	24 mo.	24 mo.	24 mo.	Right eye — 0 Left eye — useful vision
7	70	14 mo.	30 mo.	24 mo.	20 mo.	0
8	54	22 mo.	48 mo.	0 (deaf)	48 mo.	Left eye — 0 Right eye — useful vision
9	75	18 mo.	48 mo.	18 mo.	36 mo.	Left eye, Right eye } With correction using both eyes 10/70
10	48	20 mo.	36 mo.	30 mo.	48 mo.	0

* Some of the children indicated as having no vision appeared to look vaguely at bright lights. This seemed to be of no value to them in getting about.

† Useful vision indicates ability to distinguish an object held near the eye but vision not measurable by the usual standards.

Table 2.—*Results of the Psychological Tests and Other Evaluations of the Blind Prematurely Born Children*

			First			Second	Third		Fourth	
Case No.	Weeks of Prematurity	Birth Wt.	Age in Weeks	Gesell Test Dev. Quot.	Age in Months	Play Evaluation and Parent Interview	Age, Yr. & Mo.	Psychological Testing	Age, Yr. & Mo.	Final General Evaluation from Observations and Biographical Material
1	12	2 lb.	27	100	25	Exploration of the toys very limited; walked holding onto furniture and explored room; mother had difficulty reaching him verbally; seems to be withdrawn, and emotional problems may be contributing to poor behavioral functioning	2- 5 4	Vineland 54 Vineland 66	4	Retarded behavioral development primarily on basis of emotional disturbance; intellectual potential probably near normal; family accepting psychiatric help; general health good; no vision
2	12	2 lb. 3 oz.	39½	116	26	His walking, exploration of the room and of the toys impressive; biggest lack was language; normal mentality still seemed probable; emotional conflict with parents evident	2- 9 3-10	Hayes-Binet Estim. 104 Vineland 50	4- 4	Retarded behavioral development seems to be largely on an emotional basis; psychiatric help is in progress; average intellectual and social development expected; general health good; no vision
3	10	2 lb. 3 oz.	53	102	38	Exploration of the toys limited though initially she seemed interested; talked to herself in jargon of her own; ignored people around her; poor behavioral function may be on basis of emotional withdrawal	4- 7	Vineland 64	5- 3	Normal early development suggests basically normal potential; regression after 2 years of age was associated with eye pain, surgery, and family difficulties; emotional factors seem dominant; psychiatric help not accepted; general health fair; no vision
4	8	2 lb. 7 oz.	47	94	25	Walked well; talked in short phrases and had an estimated 100 word vocabulary; interest in people and social situations good; considered mentally and socially normal	2-10	Hayes-Binet 97 Vineland 81	4- 5	Mentally and socially normal; takes care of own needs; anticipated she will attend a regular kindergarten; general health is good; no vision in right eye; sees large objects held close to left eye
5	11	2 lb. 10 oz.	53	100	29	Her play was extremely complex; could catch a ball; adapt to reversal of the form board with few errors; conversation expansive; gave her full name and correctly identified herself as a little girl; no question about her good mental and social development	3- 1	W. I. S. C. 123+ Vineland 122	4- 8	She continues to be mentally and socially advanced; present emotional problems mild and realistically related to her father's serious illness; should do well in an integrated school program; general health good; no vision
6	8	2 lb. 12 oz.	41	103	32	She had enough vision in her left eye that she could identify and name objects in a picture; performed at a 30-34-month level on the Gesell scale and was given a developmental quotient of 100; language and social behavior suggested potential better than this	2- 9	Hayes-Binet 97 Vineland 120	4- 5	This child impresses one as a charming, confident, friendly, intelligent girl; uses the vision in her left eye so well that her behavior is like that of a sighted child; will enter regular kindergarten and may learn to read large print in sight-saving classes later; will probably also need Braille
7	13	2 lb. 12 oz.	43	106	18	She explored the toys fully and played a game with the ball; walked all around the room with two hands held; vocalized a complicated jargon and echoed words; was considered mentally and socially normal	5- 4	Hayes-Binet 131 Maxfield-Bucholz 92	5-10	This child is doing very well in a regular school for sighted children and a special Braille program; rides a two-wheeled bicycle, ice skates and roller skates; favorite sport is fishing; general health good; no vision
8	12	3 lb. 3 oz.	47	100	17	Wears hearing aid but no observable change; may make more sounds; explores toys primarily by tapping them against his teeth or head; rubs his body and hands against large objects; ingenuity in use of tactual sensory experiences suggested a good mental potential	2-10	Vineland 33 Direct testing not possible	4- 6	General progress has been good; feeds himself and is toilet trained; is easily disciplined; interested in people and his environment; most delayed in speech development because of his severe hearing loss bilaterally; has useful though very limited vision in his right eye and none in his left eye; at present attends a play school for cerebral palsied children and has speech instruction
					23	Walks alone; feeds self with fingers; vision in right eye useful and can see objects held close to the eye; very interested in everything in his environment; mental potential still considered good	3-11	Vineland 50 Direct testing not possible		
9	9	3 lb. 6 oz.	42.5	104	22	Walked rapidly, using her vision to guide her; said many words in Spanish and some in English; on request would point to parts of her body without error; considered to have normal potential	4- 7	Hayes-Binet 82 (Examiner felt score lowered by apprehension of child) Vineland 98	6- 3	She is in the first grade of a parochia school; can read the regular primers and copies written material; speaks Spanish and English well; walks to school alone; prognosis is good; though she has a severe visual handicap, she is not "blind"; with glasses and using both eyes vision is 10/70
10	10	3 lb. 8 oz.	25	100	22	Walked holding on; vocabulary 20 words; manipulation and exploration of the toys good; no vision at all; considered to be doing well mentally and socially	2- 4 4	Vineland 104 Hayes-Binet 105 Vineland 115	4	Talks well; adjusts well to people; feeds himself and is toilet trained; explores his environment skillfully and purposefully; anticipated he will attend school for the blind that his brother attends; should do well; no vision

RESULTS

The results of the retesting of the control group of prematurely born infants with normal vision revealed none of the seven tested as mentally retarded (Table 1), assuming only scores below 80 as indication of mental retardation, except Case 2, and this child had a normal score on the Vineland Social Maturity score.

The retesting and clinical evaluation of the 10 prematurely born children with blindness as a result of retrolental fibroplasia revealed 6 children who could be considered as functioning within the normal range (IQ 80 or above) and 3 functioning at a mentally retarded level (IQ below 80) (Table 2). One child, Case 8, could not be adequately tested because of his combined hearing and vision defects. Five different observers have seen him in play situations and believe he has normal mental potential. This is based on the amount of his investigative activity and the creative variation in his spontaneous play activities.

The three blind children who were found to be functioning at a mentally retarded to be functioning at a mentally retarded level are Cases 1, 2, and 3. All three of these cases, however, have been considered by several observers to have normal mental potential that has been functionally suppressed because of severe emotional problems. The details of these problems and the conclusions of the observers are included in the biographies. It is of interest to note that these three children had the lowest birth weights. (Table 2). Their gestational ages as reported, on the other hand, are similar to those of Cases 5 and 7, who are doing well. It is also noteworthy that all three are recorded as having no vision, in contrast to Cases 4, 6, and 9, who have a little vision and are doing well. But it should also be pointed out that Cases 5, 7, and 10 also have no vision and are doing well.

Some of the physical characteristics of the 10 blind children that might have a bearing on their mental and social development were recorded (Table 3). Electroencephalograms were done on six of the children. Two of these were read as mildly abnormal. In both instances this consisted of more 1-3 cps waves being present than was considered consistent with the age of the child. It was felt that not much emphasis could be put on these findings, because of the minimal nature of the deviation from normal. One child with these EEG findings, Case 1, was in the group functioning at a retarded level and having emotional problems. The other child with abnormal EEG findings seems to be doing well mentally and socially. Furthermore, two of the children functioning at a retarded level and having emotional problems had normal EEG's.

The only child with neurological findings was Case 8. This is the child with bilateral deafness. He was considered to be somewhat ataxic when seen in the first year of life. When examined at 4 years and 6 months of age, he was walking well and with a normal gait. However, both knee jerks seemed to be hyperactive. He walked without support by 22 months of age, which is comparable to the other children.

Though several of the children had rather small heads (Table 3), there was no apparent correlation of head size with mental or social performance (Table 2).

All of the children were considered to have no vision when they were first seen. During the follow-up period three of the children, Cases 4, 6, and 8, developed useful vision in one eye of a very limited nature. They are still regarded legally as blind. One child, Case 9, developed sufficient vision to be able to read large print with glasses. She would look vaguely in the direction of a bright light. This was not considered useful, and these children were classified as having no vision (Table 3).

The age of successful development by the blind children of four self-help tasks was de-

termined (Table 4). These tasks were (1) walking without support; (2) feeding self with a spoon; (3) talking in sentences; (4) toilet training (indicating toilet needs). The three children (Cases 1, 2, 3) considered to be functioning at a mentally retarded level were not doing any of the items except walking without support when they were last seen at 4 years of age or older. One child, Case 3, did talk some in sentences at 2 years of age and then stopped talking. Two of these children were no slower in walking without support than several of the other children who ultimately did well. It would appear that the tasks more related to social-cultural factors were the most adversely affected.

The average age for the successful accomplishment of the task of walking without support was 20.4 months for the entire group. The average for the three retarded children was 23.3 months. The three mentally normal children with no vision walked at an average age of 17.3 months. The mentally normal children with vision excluding the deaf boy, Case 8, walked at an average age of 21.3 months. It would appear that the small amount of vision did not significantly aid them in learning to walk. In fact, with respect to all of the other tasks the three mentally normal children with some vision and the three without had essentially equivalent average ages of success.

The deaf-blind boy learned to walk without support almost as early as the rest, but the other tasks were delayed, though no more than the maximum time for others in the group. He has not learned to talk but this is in progress, and it is anticipated that he can be taught to talk. It would seem that he does hear some sounds, especially with his hearing aid, but adequate testing has not been possible as yet. This small amount of hearing undoubtedly helps him, as does the small amount of vision in his right eye. Nevertheless, it is very difficult to communicate with him. His progress to date is a great tribute to his parents.

Tabulation of various characteristics of these children does not adequately describe their development, though it does aid in emphasizing various aspects of development for comparative purposes. The biographical summaries of the development of all 10 of the blind children are included to give a more complete picture of their development. This also permits a more critical evaluation by others of some of our conclusions.

COMMENTS

The greatest evil that can befall a blind child is to be judged mentally retarded early in life and thereby be deprived of any opportunities for intellectual development. Almost as serious for both the blind child and his parents is the failure to recognize a child with serious mental impairment early enough to spare both the torment of trying to achieve impossible goals.

It has been our experience from this study, and requests to examine other blind children that have come incident to this study, that the most difficult age period in which to evaluate a blind child is after 1 year of age and before language is well developed at approximately 3 years. As indicated in Table 4, common cultural-social items are delayed in development, even in children who later prove to be mentally normal on intelligence tests. These items were even further delayed in the severely emotionally disturbed children. Furthermore, in these latter children, language is very delayed in developing, thus eliminating this avenue of intelligence testing. The outcome of the three cases we have judged to have normal mental potential that is not manifest because of their emotional disturbances is, of course, still in doubt.

Some of the other children gave outside observers and sometimes their parents cause

for concern regarding their development, between the ages of 18 months and $2\frac{1}{2}$ years. In these instances, as with all of the children, biographical information of their activities at home, relationship with their siblings and parents, and general play activities, were often more helpful than any tests.

Our observations on the social development of these children were similar to the findings of Maxfield.[18] On the basis of her experience with blind children, she has developed the Maxfield-Bucholz Social Maturity Scale for blind preschool children. We chose to use the Vineland Social Maturity Scale because of our greater familiarity with it. In the use of this scale there was some revision of the scoring to allow for the blindness. We found this a very useful evaluating tool.

After some experience with blind infants and preschool children, the quality of their play and interest in their surroundings impresses one as an important method of evaluation. The imagination exhibited in inventing ways of exploring new objects is impressively suggestive of good mental functioning. This is noted repeatedly in the biographical notes of the workers of the Field Service for the Preschool Blind.

The original study of these 10 blind children demonstrated that the Gesell Test is applicable to blind prematurely born infants in the first year of life.[11] All of the infants scored within the normal range. On subsequent follow-up, six of these children are definitely mentally normal. The deaf-blind boy is performing well for a child with such a double handicap, but one cannot be certain of his mental development. The remaining three children are functioning at a mentally retarded level. However, their poor level of functioning would appear to be on the basis of emotional problems. Two, Cases 1 and 2, have begun to improve some since the acceptance of psychiatric help by the parents. The parents of the third child have not accepted any psychiatric help.

From these observations and the previous comments regarding the difficulty of evaluating blind infants in the toddler period, it would appear that development testing of blind infants in the first year of life is a significant adjunct to any evaluation program. It has been of considerable help to the parents, doctors, and field workers to have this early evaluation as a source of encouragement in working with the children. Otherwise it was not until the children had good language development that they had any generally accepted evidence that the children were normal mentally. It is interesting to note that Nelson and Richards[19,20] found a better correlation between infant testing at 6 months and mental test scores at 3 years than between 12 months and 3 years. These were normal children with vision. They related this to the infant test structure.

In reviewing the biographies of these children, one finds that the role of the family in aiding these children achieve their full potential for development is impressive. In early infancy this seemed to be a matter of giving the infant the security of acceptance and a wide range of sensory and emotional experiences. In the toddler period, the children needed a feeling of confidence in themselves to move on to independent action and self-help. Some of the families seemed to be able to aid them in this more than others. Often the field workers could help some by encouraging the parent in allowing the children more independence and by giving the parent confidence in the child's abilities. Then the children needed an expanded social experience with children their own age and adults outside the home to ready them for schooling. This is a trying time for the parents, who are concerned about the attitudes of other adults toward their blind child. They are also afraid that the child will not be able to play successfully with other children.

The fear of the attitudes of other adults was often justified. The blind children were not accepted in some nursery schools or play groups by the adult directors. One child guidance clinic refused to accept a case because the child was blind. However, other child-

ren accepted the blind children well. Sighted children will readily include a blind child in their play, especially in the nursery school age period.

Only two of the children are in elementary school and both are in schools with sighted children. One of these children sees enough to read the large print of primers but the other is totally blind. She attends a special braille program in the school. So far she is doing well. It will be interesting to follow the rest of the children as they go through elementary school.

The development of these blind children in the preschool age period has been a pleasure to observe and surprising in its normal progression for most of the children, despite their additional handicap of premature birth.

BIOGRAPHIES OF THE TEN PREMATURELY BORN CHILDREN BLIND AS A RESULT OF RETROLENTAL FIBROPLASIA

Case 1.-- This boy was born March 19, 1954, of Japanese parents 12 weeks prematurely. The pregnancy and delivery were uncomplicated. His birth weigth was 2 lb. (904 gm.). Retrolental fibroplasia was diagnosed at 3 months of age. The retina of the right eye was described as totally detached and that of the left eye as incompletely detached. He has no vision at the present time, though at times he may look toward a bright light.

The parents have found it exceedingly difficult to accept this child's blindness. One relative reprimanded the doctor severely for saving the child's life. The parents still have not informed the maternal grandmother of his blindness and she has not seen him. A brother, 4½ years older, has the closest relationship in the family to this boy. There are no other children in the family.

First year (0-1).-- During this year there was continual searching on the part of the parents for a cure for his blindness. He was kept in his crib most of the time, overly dressed and often surrounded by pillows. Toward the end of the year, after much encouragement by the field worker, the child was allowed on the floor to play and was given more freedom.

He was first tested at 27 weeks of age, when he performed at an estimated 15-week level, which was compatible with his age corrected for 12 weeks of prematurity. He did best in the prone position, rocking on his stomach with arms and legs extended. When nursing he would pat his bottle. These are 20-week items. He held the ring indefinitely and had a spontaneous social smile and chuckled. His social responsiveness was considered surprisingly good.

However, during the remainder of the first year his development was slow. By the end of the year he was just able to sit alone. He continued to seem happy and to be socially very responsive, especially to his brother.

Second Year (1-2). -- His mother seemed unwilling to let him develop independent action when he was ready for it. At 16 months he was still on pureed foods and would not touch any food or hold his bottle. At 17 months he stood holding onto furniture and said "ma-ma." By 2 years he walked freely around the house holding onto furniture, but his exploration of toys was limited to banging and he seemed apprehensive in new situations.

Third Year (2-3). -- He was seen for a play evaluation at 25 months, at which time it was noted that his exploration of toys was extremely limited. He would either bang them

on the floor or flick them with his finger. He did explore the room by walking, holding onto furniture, and played a game of running around his mother, clutching her skirt. Despite this seeming social relationship with her, it seemed difficult for her or the examiner to break into his repetitive activity.

At 29 months of age the entire family went on a two-week auto trip and following this almost all motor activity ceased, except for flipping objects with his hands or tapping his teeth. He seemed to shut off all relationship with people, and his mother's voice elicited no response. By 32 months he was responding again. He could walk without assistance and seemed happier. He permitted more personal contact and would say a few words, such as "okay, car, cookie." However, shortly after this he developed a severe sleep problem. He would awaken at 1:00 A.M. and cry and scream until 3:00 a.m. This lasted several months. Sedation did not help. The sleeping problem was somewhat improved by 3 years.

A Vineland Social Maturity Test given at this time was scored as 54. Though no direct psychological testing could be done at this time, his behavior suggested to the psychologist severe emotional disturbances as a predominant factor in his poor functioning.

Third Year (3-4). -- The mother became increasingly concerned about his withdrawn behavior and his slow development. She wanted help, and an effort was made to get the boy into a child guidance clinic and nursery school. They rejected the case because of the blindness. The field worker went to the home frequently and he developed a close relationship with her. The mother perceived this and was able to talk about her own difficulty in establishing a relationship with the boy. Finally, some help in child guidance was obtained for the mother, and an arrangement was made for an experienced nursery school teacher to spend one hour a day with him at his home. Progress has been slow, but he seems more responsive to people and especially to his mother. He sleeps well, his vocabulary is increasing and he tolerates being placed on the toilet. He still refuses to feed himself.

The question, of course, remains whether this boy is primarily emotionally disturbed and, therefore, functioning at a retarded level or whether he is primarily mentally retarded owing to organic brain damage. An electroencephalogram was done at 4 years of age and was read as a mildly abnormal EEG because of the increased prominence of slowing during light sleep over that one would expect for patients of his chronological age. This was considered a minor deviation. His good early development, especially in the social area, has been assumed to be a sign of possible normal potential in this case. He seemed to regress in his second year. It is hoped that with psychiatric help for the child and family, he may achieve a near normal development.

Case 2. -- This boy was born on Nov. 27, 1953, 12 weeks prematurely. His birth was 2 lb. 3 oz. (990 gm.). His mother had had three miscarriages and one premature infant of six months' gestation who died at birth. She stayed in bed throughout her pregnancy with this boy. He was discovered to have retrolental fibroplasia before he left the hospital at $2\frac{1}{2}$ months of age. He was considered then to be completely blind. He may see bright light now, although this is questionable. His general health has been good. There have been no other children.

At first the parents said they were so happy to have a live baby that they did not care if he was blind. The father was almost aggressively defensive and was unable to be critical of anything the boy did or of his reactions to the boy. His expressed motivation was to make the boy happy, and to do this he tried to entertain and amuse the child. He was unable to modify this as the child grew older and attempted to become independent. The mother was disappointed in having a blind child, but could not express or recognize this because of her husband's attitude. She became very fearful about the boy's health and

safety. She was afraid to have him move about, thinking he would injure himself.

First Year (0-1).-- This boy was first seen for Gesell testing at 39 weeks and 3 days of age. His best performance was standing at the rail of the crib when placed there and bringing the cube against the cup in the table top situation. These are 36-week items. At a 32-week level, he did all of the items except sit without support. He was given a developmental level of 31 weeks, which was 4 weeks in advance of his corrected age of 27 weeks. He, therefore, was given a developmental quotient of 115.

At 10 months he could sit well without support, but was kept confined to a folded sheet on the rug because the mother feared the dog hairs on the rug might be injurious to him in some way. By 12 months he was moving about in a walker and would drink from a glass. He was not allowed to touch food because this caused a mess.

Second Year (1-2).-- At 15 months the mother felt he could not stand except when holding onto her. The field worker helped her to accept letting him stand holding onto furniture and other objects. At 19 months he wanted to walk everywhere holding his mother's hand. This occupied most of her day. He could creep very fast, but the mother feared he would bump his head. He was allowed to finger feed himself some table foods.

At 22 months he was beginning to respond to toilet training. He walked well holding on and took occasional steps alone. He did not talk. His mother dressed him on the bathinette and kept him in a play pen most of the time. He was becoming irritable and demanding. He refused the bottle and also milk from a cup.

By 24 months he was described as irritable, resistant, showing little personal relationships with outsiders except an aunt. He was a severe sleep problem. His father walked with him every night to put him to sleep. He rubbed his eyes a great deal. He could walk alone and climb a ladder to his slide and invented a game of rolling a ball up the slide and then catching it on the way down. His mother said she felt closer to him. He was increasingly demanding of his father and screamed to be held. The father was beginning to resent his demands.

The parents state that he was beginning to talk, feed himself, and to be toilet trained at about 2 years of age. Then they started to put calsulfhydryl drops in his eyes. These were so painful to him that they only continued them for two weeks. However, the father felt that he regressed behaviorly during this time. After the drops were discontinued they continued to give him sulfhydryl powder in his food for six months. There was no improvement in his vision.

Third Year (2-3).--He was seen at 26 months for a play evaluation. His walking and his exploration of the room and of the toys was very impressive. His greatest lack was in the language area. He was reported to say a few words, but no combinations of words. In the interview his mother described his fear of the toilet and resistance to toilet training, his inability to go to sleep at night, and his unwillingness to hold a cup or spoon. The conflict between the mother and child on all problems of socialization seemed to be overwhelming the mother. She was obviously indecisive in all her actions. At that time he was considered to show some evidence of normal mental potential, but significant emotional disturbances.

During the remainder of the year this boy made little progress. His language did not improve; his sleep problem persisted, and he became more aggressive towards his mother. His father became more punitive as he was unable to keep up with the boys's demands. Psychiatric help was advised and offered in various forms and was not accepted.

He was seen at 38 months for psychological testing. He was hyperactive, perseverative, and highly distractable. He was able to perform the nonverbal items of the Hayes-Binet test at a 36-month level. This was not considered a valid test, but an estimated score of 105 was given. On the Vineland Social Maturity Test he was given a score of 73. The father was observed to be very anxious, overprotective and oversolicitous. He attempted to anticipate and gratify all of the boy's needs. The tester (R.W.) felt that there was suggestive evidence of organic brain damage compounded by difficulties in the parent-child relationship.

Fourth Year (3-4).-- During this year the parents made a greater effort to evaluate their feelings toward their son and to be more critical of their management of him. They found more activities for him outside the home. He enjoyed going in the neighbor's swimming pool, although he did not respond to other children in the pool. He was accepted in a small church nursery school. The teacher accepted him well, and he tolerated the other children but did not participate in their activities. His hyperactivity, aggressiveness, and negativism were major problems for the teacher.

Toward the end of the year the father began to do all of his work at home. This put more pressure on the child and the mother. The sleeping problem was aggravated. However, the boy began to babble some with his mother and occasionally would go to the toilet independently.

At 46 months of age he was seen for psychological testing by R.W. a second time. He was less hyperactive and distractable and showed improvement in his ability to relate to others. His over-all behavior evidenced a decidedly higher level of integration. Nevertheless it was still not possible to do valid intelligence testing. His language development was still very poor, but his comprehension was very good. Though on a Vineland Social Maturity Scale he scored 50, it still seemed likely that his mental potential might be normal.

Present Evaluation.-- He is now 4 years and 4 months of age. He is very hyperactive and limited in his ability to relate to people. He does not talk in sentences, but says words. He will feed himself some and will sometimes go to the toilet. He will sleep through the night only if he is with his father. The family has sought help from a child guidance clinic. This clinic has recommended psychiatric care for this boy outside of his home and guidance for the parents while he is away. This has been arranged. An electroencephalogram attempted at this time was unsuccessful because of inability to sedate him adequately even with large doses of chloral hydrate.

The general opinion is that this boy is primarily emotionally disturbed. If the proper kind of help is given, it is felt that this boy can achieve a reasonably normal level of mental and social functioning.

Case 3. -- This girl was born Feb. 2, 1953, 10 weeks prematurely. Her birth weight was 2 lb.3 oz. (990 gm.). The pregnancy was uncomplicated until hemorrhage initiated premature labor and delivery. The presentation was vertex and no anesthetic was required during the delivery. The baby did not cry immediately, presumably because of mucus obstruction in the trachea. Respirations were established with difficulty. She was diagnosed as blind, as a result of retrolental fibroplasia, by 3 months of age. Her blindness has been complete to the present, though she may perceive bright light. Between 7 months and 3 years of age she had recurrent glaucoma with ocular tension up to 84. At first this was controlled medically, but ultimately surgical treatment of the glaucoma was necessary. This was followed by some iridocyclitis. At one time removal of both eyes was recommended because of apparent persistent pain despite reduced intraocular tension. There was conflicting medical opinion relative to this and this was never done.

Her parents had wanted a child for a long time and this girl was their first born. At first they seemed to be very close to her and enjoyed her very much. However, their feelings about her blindness were very deep and they were very concerned about what other people thought of her. They found it difficult to talk about her blindness to others. Gradually the mother's relationship to this child seemed to be that of a distant observer. There were many pats and kisses but she was tense in expressing real affection. She often talked baby talk to this child in a high, unnatural voice. She became well informed on medical terminology and on blindness and continually searched for opinions from many doctors but was unable to accept any of these opinions.

The marriage became an unhappy one with several separations. Another child, a beautiful normal girl, was born when the first girl was 13 months of age. The relationship between the two girls is not a close one.

First Year (0-1). -- In the first few months of life the child cried a great deal, had diarrhea and vomited. Goat's milk was said to have cured the diarrhea. By 5 months of age she was a happy baby, responsive and smiling. At 7 months of age she stood and bounced when held supported, held toys, played with her own hands, and laughed aloud. By 11 months of age she could pull herself to a standing position, cruise along the rail of her crib, feed herself with her fingers, jabber and imitate sounds, and drink from a cup. She was described as a merry, active youngster. There were, however, two major problems. She had a bizarre sleep routine, preferring to be awake until well after midnight and to sleep most of the day. The parents either could not or did not try to change this. She was also noted to have some swelling of the eyes, and glaucoma was diagnosed. Though tensions as high as 48mm. were measured, she showed little evidence of pain and medical management seemed to be satisfactory.

Second Year (1-2).-- A developmental test was done at 53 weeks of age. She sat well without support and could pivot in the seated position. She pulled herself to a stand at the rail of the crib and cruised along it. She could walk with only one hand held. She used her index finger well in exploring items and poked at the clapper of the bell to explore the source of the sound, and removed the round block from the form board. She said "ma-ma" and "da-da" and could wave "bye-bye" and "pat-a-cake." She drank well from a cup. She was given a developmental level of 44 weeks, which was considered compatible with her corrected age of 43 weeks. Her developmental quotient was 102. At that time the comment was made that both parents enjoyed playing with her and seemed to give her adequate affection and stimulation.

Shortly after this testing the intraocular tension increased in both eyes, and surgical correction was necessary. Following this she became fretful and seemed to have more pain, even though the intraocular tensions were normal. It was thought that she might be suffering from iridocyclitis. None of the treatments seemed to relieve the distress. She slept poorly even with sedation, and her appetite diminished and she became easily fatigued. Her weight was only 17 lb. (7,710 gm.). This period was described as "veritable hell" for the entire family. Her sister was born about one month before the eye surgery.

At 18 months of age she was still eating poorly and was fretful a great deal of the time. By 21 months she was happier and more friendly and her sleeping problem was less severe. Her vocabulary was large and she talked in phrases and short sentences, answered questions and enjoyed saying difficult words. She was very active. She enjoyed her swing and went in and out of the house into the yard alone. She was eating better.

Unfortunately, right after this the mother had to leave the family a few days and return to her home town to take care of her father. Then the entire family returned to her

father's home to settle family affairs. This child did fairly well in this strange place but became very touchy and sensitive.

Third Year (2-3).--After the family's return from this trip she seemed to regress. She remained active and eager in her manipulation of toys but she preferred solitary play. She did not relate to people other than her parents. She chattered to herself in clear speech but would not talk to others. Briefly, she was enrolled in a cooperative nursery school. She did not relate to the other children but would accept close contact from theteacher. By the end of the year the parents felt she had regressed both physically and mentally. Theyattributed this primarily to eye pain. It was found that there was an increase in the tension in the left eye. Enucleation of both eyes was recommended by one ophthalmologist but not by another. The parents were undecided. At this time her speech was still clear and she had a large vocabulary but talked mainly to herself. She rode a tricyle and would climb up the steps of a slide.

Fourth Year (3-4).-- At the beginning of this year she had pneumonia and was very ill. After this the parents stated that she seemed to have cramps in her legs and intestinal distress. Generally she was unhappy and slept poorly. She would cry continuously for long periods of time and could not be consoled. She would stay in her own room. Her speech was hardly understandable. She climbed on her parents and on other people as if they were furniture. Various sedatives and tranquilizers were only of temporary help.

At 38 months she was seen for play evaluation. She showed considerable interest in various toys for brief periods but her exploration of these toys was limited. She talked to herself in a jargon of her own. Occasionally she would say intelligible words, but these were generally not directed at anybody in the room. In general she ignored the people around her. She seemed to hear what was said but gave no recognition of this. The impression was that her mental potential might be reasonably good, but that she was becoming progressively withdrawn. At that time she weighed 23 lb., was 37 inches tall, and had a head circumference of 46.5 cm.

The parents were very concerned about her physical development and her unexplained periods of distress. For this reason she was hospitalized at 42 months of age for observation and laboratory studies. Laboratory tests revealed the following: fasting blood sugar 97 mg.; phosphorus 5.1 mg.; calcium 5.3 mEq.; B.U.N. 11.5 mg.; hemoglobin 11.7 mg. ; x-ray studies of the skull, upper and lower gastrointestinal tract and an I.V. pyelogram were all normal; wrist x-rays for bone age were estimated as a carpal age of 38 months; an electroencephalogram was normal. She had no attacks of distress while in the hospital. A psychiatric consultant felt that her regression was primarily on an emotional basis. Psychiatric help was recommended at that time but the parents did not wish to accept this kind of help.

Briefly she seemed to improve somewhat after her hospital stay. She began to repeat nursery rhymes previously known but otherwise had no speech. By 48 months she had become more aggressive and would bite herself and her parents. In play with toys she mouthed everything. Her motor activity involved mainly rhythmic and circular body movements. Her emotional responses were inappropriate. Her greatest response was to "rough house play," which brought on gales of laughter.

Fith Year (4-5).-- Early in this year the parents attended some psychiatric group meetings for a few weeks. During this time the girl improved some in that her perseverative circular body motion could be interrupted and her activity could be redirected. She appeared more relaxed. Her play with toys was more meaningful. She seemed more aware of her environment.

At 55 months of age she was seen for psychological testing. It was not possible to do intellectual testing in an objective manner at that time, because she was too withdrawn. She did perform a few items on the Hayes-Binet test at a 42-month level. The tester's general impression was that the depth of emotional disturbance in the child was sufficient to account for the behavior retardation. During the remainder of the year she seemed to make no progress. The parents became very hostile to the idea of psychiatric help. One doctor informed them the child was severely brain damaged, and placement in the state institution for the mentally retarded was considered by the parents. A second electroencephalogram was normal. Another doctor consulted advised psychiatric help. When last heard from the child was 64 months of age, and the parents were taking her to still another diagnostic clinic and were dissatisfied with it.

This child developed so well in the first two years of life it seems likely that she had and probably still has a reasonably normal intellectual potential. It would seem that her retarded functioning at the present time is primarily due to severe emotional problems. To date every effort to get this family to accept psychiatric help has been unsuccessful except for one brief period. It is still possible that this kind of help may be accepted and that this child might be returned to a reasonably normal intellectual and social functioning level.

Case 4.-- This girl was born Oct. 27, 1953, reportedly only 8 weeks prematurely. Her birth weight was 2 lb. and 7 oz. (1,105 gm.). The pregnancy had been complicated by several threatened miscarriages with spotting. The baby was delivered by cesarean section because of bleeding, presumably due to placenta previa. Retrolental fibroplasia was diagnosed while she was still in the hospital. She was thought to be completely blind in early infancy, but at present seems to have some peripheral vision in her left eye and may be able to distinguish some large objects. She certainly sees light.

There are three older children in the family, who were ages 18, 16, and 11 at that time. The family has always been in a poor financial state. They have lived in low-cost furnished apartments with no major effort made to improve the shabbiness of these apartments. On the other hand, the family has been cohesive. The older children have assumed financial responsibilities for themselves and sometimes for the entire family. The older daughter is now self-supporting and attending a university. They all shared in the care of this baby and had good relationships with her. She was always included in family camping trips, picnics, and other activities.

First Year (0-1).-- This girl was an easy baby to take care of, according to her mother. At 6 months she sat with support and would hold toys; by 7 months she stood with hands held, and at 8 months would sit momentarily alone and would "pat-a-cake." She was first seen for Gesell testing at 47 weeks of age, at which time she sat well without support; stood holding the crib rail when placed there; took the bell by the top of the handle, had a crude release of the cube; used her index finger to explore; and said "ma-ma" and "da-da." She was very deliberate and slow, but thorough in her exploration and manipulation of each toy. Her mother described her as a quiet thoughtful, happy child. At that time she localized all objects by sound and did not appear to use any vision. She was given a developmental score of 37 weeks on the basis of her over-all performance. Her corrected age was 39 weeks and this gave her a developmental quotient of 94. By one year of age she was reported to be eating all table foods, chewing well, and would feed herself a tuna fish sandwich.

Second Year (1-2).-- She started the year by learning to handle a cup herself and to pull herself to a stand on furniture. By 18 months she could creep everywhere and could walk with two hands held, but did not like to do this. There was some concern about her left leg, because she tended to drage it (hip x-rays were negative). She enjoyed going

with the family to the store. She was a very happy child.

At 2 years she seemed fretful and was eating poorly. She also had trouble going to sleep. Her mother thought her carious teeth were hurting her. She could stand momentarily alone, but not walk. She was toilet trained and her vocabulary was increasing rapidly.

Third Year (2-3).-- She was seen for play evaluation at 25 months of age. She walked well and talked in short phrases and had an estimated 100-word vocabulary. Her general interest in people and social situations, as well as objects, was very good. She was considered to be developing normally mentally and socially. She had light perception in her right eye and possibly she could perceive gross objects. Her weight was $21\frac{1}{2}$ lb. and height 33 in.

During the remainder of the year she became increasingly interested in and active in the world around her. However, her appetite was described as poor, and she had difficulty in going to sleep at night. She liked to ride her tricycle. She was interested in being with other children and enjoyed chasing the family dog. She talked in long sentences. She began to assert herself at home, and her mother considered her at times a disciplinary problem.

She was seen at 34 months of age for psychological testing. She cooperated well and was given a score of 94 on the Hayes-Binet test and of 81 on the Vineland Social Maturity Test. The mild retardation in social progress was attributed to her blindness. Her overall adjustment was considered good.

Fourth Year (3-4).-- The feeding and sleeping problems gradually resolved during this year. She learned to play long periods of time by herself with blocks and dolls and other toys. She enjoyed long conversations and story books. She learned to climb stairs well. Briefly, she was in a nursery school where she adapted well. She could not stay because the family moved.

Present Evaluation (4 Years 5 Months).-- She now takes care of all of her own needs, such as eating and toileting. She does not dress herself. She has good balance and can roller skate. She has excellent use of language and enjoys conversation. She enjoys being with children and adults and initiates her own play activities. An electroencephalogram done at this time was normal. She is considered normal mentally and socially. It is anticipated that she will enter a regular kindergarten and then go on to an integrated school with sighted children.

Case 5.-- This girl was born Aug. 8, 1953, 11 weeks prematurely. Her birth weight was 2 lb. and 10 oz. (1,190 gm). The mother's pregnancy was reported as normal. She has one sibling, a brother 4 years older, who was born three weeks prematurely, but is perfectly normal. She was suspected of being blind at 4 months of age, but not definitely diagnosed as having retrolental fibroplasia until 6 months of age. She was considered to be totally blind at that time and she still is, although she may perceive bright light.

The parents considered her extremely fragile at first and expected very little from her. They were slow to give her adequate stimulation. However, the mother seemed to have great capacity to learn from her child and gradually stimulated her more and more. The relationship between the older brother and this girl was very good throughout. The total family relationship seemed strong and the mother received a great deal of support from her husband. The family have been financially well situated and both parents are intelligent people. Unfortunately, in the past few months the father has been critically ill.

First Year (0-1).-- This girl was able to sit with little support by 8 months and could feed herself toast and cookies. At one year she was seen for Gesell testing. She could sit indefinitely without support. She stood at the crib rail and lifted her foot, but did not cruise. She did walk with both hands held. She drank from a cup and did sequential cube play. These were her best performances. She did essentially all of the items at 40 weeks except those requiring precise hand-vision coordination. She was given a developmental age of 43 weeks. Her corrected age was 42 weeks. Therefore, she had a developmental quotient of 100. Subjectively, she impressed one as better than the scoring would indicate because of her extreme interest and enthusiasm during her play.

Second Year (1-2).-- Comprehension of language came in rapidly by 15 months and at 16 months she took a few steps alone and said "ma-ma" and "daddy." At 22 months she could run and name almost any object and sometimes used words to describe her activity. By 2 years she talked in sentences and played word games with her father. She did not like to be alone and followed her mother everywhere around the house. Sleeping was a problem. She cried at night and got in bed with her mother.

Third Year (2-3).-- Socialization proceeded rapidly. Toilet training was complete by 28 months. She participated in household chores, such as setting the table, at this time. Play evaluation was at 29 months. Her play was extremely complex, including catching the ball when it bounced against her body and adapting to reversal of the form board with a few errors. Her conversation was expansive. She gave her full name and in response to the question "was she a boy or a girl" she answered correctly after some hesitation. Her language and comprehension seemed to be nearly at a 3 year level. There was no doubt in the observer's mind that she was functioning at or above a normal level mentally and socially. It should be added that her parents still found it necessary to feed her. However, by 3 she was feeding herself. During the remainder of the year her development continued rapidly. The sleep problem was resolved by steady firmness on the part of the parents. Her chief problem was fear of being away from her mother even for a few minutes.

Fourth Year (3-4).-- She proceeded to gain more and more independence so that by the end of the year she could spend a day away from her mother without fear. She carried out complicated errands and enjoyed a visit to a nursery school. Plans were made for her to attend nursery school.

She was seen at 37 months of age for psychological testing. Her good language development and social adjustment made testing easy. She was given the Wechsler Intelligence Scale for Children and achieved a score of 123. On the Vineland Social Maturity Scale she received a score of 122. There was no question about her advanced abilities despite her complete blindness.

Present Evaluation.-- She entered a nursery school for half-day sessions and got along well without her mother. Attendance was irregular because of colds, and she was finally withdrawn because of her father's illness. The anxiety in the home about her father's illness brought on her fear of separation from her mother again. Aside from this problem, she does everything appropriate for her age and is alert and friendly and eager to learn. Her general health has been very good. It is anticipated that she will enter an integrated school program with sighted children and will do well.

Case 6.-- This girl was born Nov. 15, 1953, eight weeks prematurely, and weighed 2 lb. 12 oz. (1,245 gm.). The mother's pregnancy was normal except for some spotting at two months and premature rupture of the membranes two weeks before delivery. The labor was short, but normal. The mother was known to be Rh negative, but there were no problems with hemolysis in this child. The mother has had five subsequent pregnancies with only one living child and he required an exchange transfusion. He is $2\frac{1}{2}$ years younger than this girl and is apparently normal.

Initially she was considered to be totally blind. The retina of the right eye is said to be completely detached, while that of the left is only partially detached. She now has useful vision in her left eye and can distinguish objects and colors. During her second year of life she had repeated respiratory infections and whooping cough and did not gain weight and at 18 months of age she was comatose for one day, said to have been owing to inhaled toxin from a plant spray mixture. She has been well since.

Her parents are intelligent and self-confident people who seem to have a strong relationship with each other. They mutually talked about their feelings about the blindness of their daughter and said that they came to terms with the problem early in her life. The mother said that at first it bothered her when other adults mentioned the blindness, but this does not trouble her so much now. She is now concerned with other children's comments to her daughter. The parents seemed to accept this child well and encouraged her independent activities at the same time, including her in all family activities. Her relationship with her younger brother has been good.

First Year (0-1).-- This child immediately after birth was in an incubator for six weeks and received oxygen. She had been home for six weeks when retrolental fibroplasia was diagnosed. At that time she was returned to the hospital on the advice of her family physician and replaced in the incubator for another six weeks for gradual reduction of oxygen. She was in the incubator the second time from the age of 3 months to the age of $4\frac{1}{2}$ months.

Developmentally she subsequently did well. At 6 months she sat momentarily without support and at 8 months pulled to a stand in her mother's lap. She was seen for Gesell testing at 41 weeks. She did essentially everything at a 32-week level except the pellet items. At the 36-week level she stood at the rail of the crib, had a radial-digital grasp of the cube, hit and pushed a cube with a cube, and hit the cup with the cube. She also imitated sound, responded to her name, and fed herself a cracker. On the basis of this testing she was given a developmental age of 34 weeks. Her corrected age was 33 weeks; therefore, she nad a developmental quotient of 103. Although she later developed some useful vision, at the time it was noted that both eyes were deviated inward and she did not use vision at any time to locate an object, but felt for the toys with her hands. By a year of age she was walking all around the house holding onto furniture and the walls. The family noted that she appeared at times to make some visual responses.

Second Year (1-2).-- She began to walk alone at 15 months and said several words. She had repeated respiratory infections and whooping cough despite immunization. In the middle of this year on one morning she could not be aroused and she remained in a coma all that day. She was well the next day. It was thought that she had been poisoned by a toxic inhalant from some special spray mixtures at a neighbor's house. After this episode she continued to develop well. Her mother was very skillful in getting her to participate in the household activities. She was feeding herself well by 2 years and talked in sentences. She was also toilet trained. Her vision was definitely useful and she obviously explored objects by holding them close to her left eye.

Third Year (2-3).-- In this year she began to use her limited vision more and more and seemed to operate much like a seeing child. When seen for play evaluation at $2\frac{1}{2}$ years of age she played, talked, and socially behaved like a $2\frac{1}{2}$-to 3-year-old child. Her relationship with her parents was exceptionally good. She had enough vision in her left eye to identify objects in pictures and name them.

She was seen at 33 months of age for psychological testing. On the Hayes-Binet test she received a score of 97 and on the Vineland Social Maturity Scale she was given a score of 120.

Fourth Year (3-4).-- This girl continued to progress well. Her playmate was primarily her younger brother. She did not attend nursery school. She did take dancing lessons, which she enjoyed very much.

An electroencephalogram was read as mildly abnormal with moderate high potential and random slow 1-3 cps waves over the posterior scalp area. This amount of slow 1-3 cps activity was described as somewhat in excess of what one would expect for a patient of 4 years.

Present Evaluation (4 years 5 months).-- This child impresses everyone as a charming, confident, friendly, normal girl. She is to go to a regular kindergarten in the fall. She may later be in sight-saving classes and read large print. However, it is likely she will need to learn braille also. Her general health is good now.

Case 7.-- This girl was born June 13, 1952, thirteen weeks prematurely. Her birth weight was 2 lb. 15oz. (1,330 gm.). The pregnancy and delivery were uncomplicated except for the prematurity. She was diagnosed as blind, as a result of retrolental fibroplasia, at 5 months of age. She had no vision in either eye then. At present she can see a little in a dark room, but nothing else. The parents were young, and wanted this baby very much. She was their first child. The parents were very upset when they first learned of her blindness, but very soon the wife and husband said "This is it and we've got to help her the best we know how." One of the mother's early statements to the field service worker was, "I'm afraid I'll be sorry for her and won't let her do enough." They were eager to help the child every way possible, including not overprotecting her. They seemed to understand and accept suggestions from the field service worker very well. They appeared to be very successful in their management and understanding of this child until she was 2 years of age. After that they moved from the area and were not heard from again until the child became known to an agency for the blind in another metropolitan center. A follow-up report on this girl's present school progress was made available, and the mother wrote a lengthy follow-up report.

First Year (0-1).--This girl progressed very normally during her first year of life,and she was considered to be a happy baby. She was seen at 43 weeks of age for developmental testing. Her age corrected for 13 weeks of prematurity was 30 weeks. She sat steadily without support; stood with her hands held, and pivoted in the prone position. She had a radial digital grasp of the cube; held two cubes prolonged, and transferred objects from one hand to the other. She vocalized "da-da," imitated sounds; held her own bottle; and would feed herself a cracker. She was given a developmental age of 32 weeks and a developmental quotient of 106.

Second Year (1-2).-- She was next seen at 18 months of age. Her corrected age was approximately 15½ months. She still seemed to be totally blind, although she objected to very bright lights. Both eyes had completely opaque retrolental masses. On physical examination she seemed to be perfectly normal otherwise, except that she was slender; weight 20 lb. 8 oz. (9,300 gm.); height 31½ in; head circumference 18 in. She had been well, except for minor colds. On the play evaluation she seemed to be developing normally. She explored all of the toys fully. She played a game of rolling a ball back and forth between the examiner and herself. She enjoyed walking all around the room with both hands held. She was reported to walk up stairs with hands held and she would climb into a chair without help. She vocalized with a complicated jargon, said "mama" and "dada," and echoed words. Her favorite toys were a horn, a rattle, some blocks that rattled, a beach ball, and some keys. She did not like to hold anything soft or fuzzy like a teddy bear, or a soft doll. She would feed herself with her fingers. She generally was a happy baby. She did have some sleep problems.

She was not seen again after this, since the family moved to another city. However, she was located in that city wher she became known to an agency for the blind there. The report received from them was as follows: In the first grade she was in the regular classes part of the time, and in braille classes the remainder of the time. At 5 years and 4 months of age she was given psychological tests. On the Hayes-Binet test she received a score of 131, and on the Maxfield-Bucholz social maturity test a score of 92.

Her mother reports enthusiastically of her progress in school. She can read three primers in braille. She also has many outside activities. She rides a two-wheeled bicycle,

roller skates, ice skates, and loves to go fishing. She also sings well, and takes singing lessons. Her mother states, "I can remember when I found out she was blind, the only thing I could think of was how empty and lonely her life would be. How wrong I was." She is reported to be in good health, and at 5 years and 10 months of age weighs 56 lb. and is $46\frac{1}{2}$ in. tall. One would anticipate that she will continue to do well and have a full life.

Case 8.--This boy was born Oct. 6, 1953, 12 weeks prematurely. His birth weight was 3 lb. 3oz. (1,445 gm.). This boy's mother has had seven pregnancies and has three live children. The first three pregnancies miscarried between the fourth and six months. The fourth pregnancy was carried to term and this boy is 7 years of age and is healthy and normal. The fifth pregnancy was of six months' duration, and this premature infant died at birth. This boy, Case 8, was her sixth pregnancy. Her seventh pregnancy was of 30 weeks' gestation, and this girl is now one year of age and is normal and healthy. The mother received estrogen and progesterone during all of the pregnancies. Her sister had two premature infants delivered after six months' gestation.

This boy (Case 8) was noted to be blind as a result of retrolental fibroplasia in the first five months of life. It was soon evident that although his blindness was complete in his left eye, he did have some vision in the right eye. At present he has useful vision in his right eye and examines all objects visually by holding them close to his eye. He guides himself visually when walking. His major problem is a severe hearing loss. Although he seems to hear a few sounds, he does not hear speech sounds, even with a hearing aid. He also has a minor orthopedic problem in that his left foot is $1\frac{1}{2}$ sizes smaller than his right foot, and his left leg is about $\frac{1}{4}$ in. shorter than his right leg.

His parents are unusual people. This boy, with his combined difficulties of blindness and deafness has presented many problems. He has not been an easy child to handle, particularly in the first three years. These people seem to have a strong family unity, and when one parent gets discouraged, the other takes over. They seemed to complement each other. Both love and understand their boy. The father has felt the need to "teach" the boy while his mother has allowed him freedom in self-investigation. They have always been firm in handling him when this was necessary. The older brother plays well with him and is very considerate of him.

First Year (0-1).--When he was first taken home from the hospital at seven weeks of age, he slept all of the time and seldom cried. Then he became very restless when awake and tended to hold himself rigid, or thrash about and bang his head. He was first seen for a developmental examination at 47 weeks of age. His age corrected for 12 weeks of prematurity was 35 weeks. When placed in the seated position, he could sit without support prolongedly, if he leaned far forward. Otherwise he tended to stiffen his back and fall over backward. He stood holding onto the rail of the crib, and pivoted in the prone position. He could pick up small objects between his thumb and index finger in a scissors grasp, and had a radial digital grasp of the cube. He also released the cube intentionally and each time he released the cube he would go after another. He held his own bottle, and could feed himself a cracker. He transferred objects from one hand to the other with great skill, using his fingers nimbly. Of unusual interest during the examination was his lack of vocalization, and his exploration of several of the toys by banging them against his head. He was also not able to localize the sound of the bell to either side of his head. However, when he was prone with his head turned to one side, and the bell was rung close to his ear, he would stop banging his head and seemingly listen. From these observations, the parents were questioned in detail about his responses to sound, and it was mutually agreed that he probably had a significant hearing loss. This was the first time the parents had considered this possibility. Although his vocalizations were limited, he had squealed and laughed aloud.

The increased muscle tone in the legs and the tendency to arch backward was of concern to the examiner, as evidence of some neuromuscular disturbance. Despite his blindness, hearing loss, and increased muscular tension in his legs, his performance was generally very good, as detailed above. He was given a developmental age of 35 weeks and a developmental quotient of 100.

Second Year (1-2).-- At 14 months of age he was seen at the John Tracy Clinic for the the Deaf and was diagnosed as severely hard of hearing. The parents were also certain of his hearing loss by this time. Despite these handicaps at 15 months he was walking everywhere holding onto furniture, and also crawling on his hands and knees. He enjoyed people and was always smiling. However, he continued to pound his head and teeth with objects as a way of sensory exploration. He also slapped his ears until they were swollen. He made some sounds, mostly grunts and gurgles.

At 17 months he was seen at a special clinic for deaf children and given a hearing aid to wear in his right ear all day. Soon after this he was seen for a play evaluation. He had not been wearing the hearing aid long enough for the parents to evaluate its effectiveness. He did seem to enjoy wearing it and seemed to listen to it. However, he did not explore the sound of anything by bringing it close to the speaker. He was making sounds more frequently, but these were monotone vowel sounds. He still liked to tap objects against his head or teeth. When he was lying down, he rubbed his hands back and forth, or rubbed his back up and down, or bounced his body up and down. He seemed to use tactual and kinesthetic experiences to their fullest to explore his environment. This was so impressive that there was little doubt that he had normal intellectual potential. There was no longer any concern about a neuromuscular disorder. The reflexes were normal, and no increased muscle tone was evident. He weighed 24 lb. $7\frac{1}{2}$ oz. (9,395 gm.) and was 30 in. tall. His head circumference was 45 cm.

At 22 months he began walking without support. He jabbered and made noises when listening to music. He finger-fed himself and would eat table foods. He was seen for another play evaluation at 23 months of age. He sat very steadily and would lean far forward and touch his head to the floor. He preferred to be standing, or on his hands and knees. He localized the toys immediately visually with his right eye. He even located and picked up a small red pellet. When he was holding a new object he tended to bring it close to his right eye for careful inspection. He did not vocalize as much when he was not wearing his hearing aid. When he was wearing it he made a great deal of noise, but mostly a wailing, siren-like sound. When the hearing aid was in his right ear, he gently poked his left ear. He was very impressive in his play, body movements, vocalizing, manipulation of objects, and interest in his environment.

Once a week he received auditory training at the clinic for deaf children.

Third Year (2-3).-- Early in this year he was given a separate hearing aid for each ear. This seemed to help him localize sounds in space. There was some difficulty getting him to use the hearing aids. He liked to take them off and use them as toys. His ability to walk and climb improved, and he became more active and adventuresome. His attention span was very short. At times it was difficult to keep him happily occupied. His main activity with toys was throwing them. He was seen by a consultant psychologist from the American Foundation for the Blind, who felt his behavior was well within normal limits for a deaf-blind child. During this period his mother took care of three foster children.

Fourth Year (3-4).-- He continued to be very curious and to gain a full experience out of every activity. He was often found under the house or in some other hard-to-get-to place. He cooperated well with toilet training, and began feeding himself with a spoon. He drank from a cup without assistance. He sought more affection and reciprocated. For a month he was very interested in light switches. He became more and more independent in his play and he would climb on and off his rocking horse alone. In walking he liked to experiment, first walking on his toes, then on his heels and limping first on one leg and then the other. Toward the end of the year, after his baby sister was born, he became "impossible to handle." He was irritable and it was difficult to please him. He tried to make his wants known and would direct his mother to the cupboard for a cookie. He had great difficulty going to bed.

at night. He seemed frightened in bed. Finally his mother moved him into the same room with the older brother and put their beds together. His sleep problem disappeared. Occasionally he would reach over and touch his brother for reassurance.

Present Status (4 Years 6 Months).-- In recent months he has seemed much happier. His attention span is longer. He is interested in how things work. He began swinging on any object he could hang onto. He learned to eat corn on the cob and to enjoy it.

An attempt was made to do more definitive hearing testing. He was reported to respond to music at 65 db. and to sound in a sound field through 80 db. A diagnosis of nerve-type deafness was reported.

He is enrolled in a play group for children with cerebral palsy. There was no other group that would accept him because of feelings about the complexity of the problem. At first he was unhappy being away from home for part of the day, and in a strange place. Gradually he has accepted the new environment and seems to enjoy being with the other children. An electroencephalogram done at this time was normal. His general health is good. It is interesting that this boy has always had periods of inactivity and irritability, which at first lasted two to three months at a time. How these periods last only a week or a few days. After these difficult periods pass, he always seems happier, easier to handle, and capable of some new activity. His attention span, for any object or play activity, is longest in a familiar environment. In a new environment his curiosity seems to keep him constantly on the move as he investigates the entire area. He has to do this independently and resists any intrusion or control.

He eats well, feeds himself well, and is toilet trained. He is easily disciplined and controlled. He is interested in people and enjoys being around children. He is generally very happy. His biggest deficit is in speech development. He has made little progress with speech to date, but it is anticipated that he will learn to talk. His hearing deficit is his major problem relative to ultimate school placement. Although his visual handicap is severe, he may have enough vision in his right eye to learn to read large print. The ideal school placement will be hard to find. He may go to the State Residential School for the Blind, where there is a special program for deaf-blind children. On the other hand, he may be able to go to a daytime school for the deaf and get along with his limited vision.

Case 9.-- This girl was born Jan. 6, 1952, nine weeks prematurely. Her birth weight was 3 lb. 6 oz. (1,530 gm.). Nothing is known of the mother's pregnancy or delivery, since she is an adopted child. The child was diagnosed as partially blind, owing to retrolental fibroplasia, at 6 months of age. It was apparent that she could see something at that age, in that her eyes made constant searching movements and she would look in the general direction of some brighter objects. It was reported that the upper nasal quadrants of the retina of each eye were involved symmetrically. The remainder of the retina appeared normal. At the present time she wears glasses to correct the myopia of -7Δ in the right eye, and $-10\frac{1}{2}\Delta$ in the left eye. With her glasses and using both eyes, her vision tests as 10/70. She is at present in the first grade, and reads from the regular first-grade primers. She is no longer classified as blind, although the degree of vision she now has was not anticipated in the first year of her life.

The parents accepted this child for adoption when she was $2\frac{1}{2}$ months of age. The child was not suspected of being blind at that time. They were obviously concerned when they did learn of her blindness when she was 6 months of age. The mother was silent and unexpressive and seemed overshelmed. The father did most of the talking for the family during interviews, and seemed to be a stabilizing influence. This baby was obtained through an agency, and the agency gave the parents every opportunity to give the baby up if they felt they

could not cope with the situation. Both the parents seemed to mature while caring for the child. In the long run the mother gave her the most warmth of affection and showed the most ingenuity in providing for this child's needs to promote good development. The family subsequently adopted a little boy from the same agency. He appears to be normal in every way.

First Year (0-1).-- At 24 weeks of age she sat propped with her head steady, brought her hands together in the midline, laughed aloud, put toys in her mouth. She seemed to be functioning at about a 15-week level, which would be compatible with her age corrected for 9 weeks of prematurity. By 42 weeks of age she could sit without support indefinitely, stood holding onto the rail, held her own bottle, fed herself crackers, pivoted in the prone position. She would look at light, but otherwise her eyes seemed to wander. She was given a developmental age of 35 weeks. Her age corrected was 33 weeks; therefore she received a developmental quotient of 104.

At one year of age, in a pediatric clinic, there was considerable concern because of her small head circumference of $40\frac{1}{2}$ cm. Her weight was 16 lb. 14 oz. (7,655 gm.) Though there were no abnormal neurological signs, her general progress was not considered normal in this clinic.

Second Year (1-2).-- During the first six months of this year, her head continued to grow at a normal rate, though it was small. At 18 months of age her head circumference was 43 cm., her height $27\frac{1}{2}$ inches, and weight was 20 lb. (9,070 gm.). She could walk across the room, up and down steps with her hands held; held her own cup; took off her shoes and socks on request. She was next seen for a play evaluation at 22 months of age. She walked rapidly, obviously using her vision to guide her. When she came to a dark spot on the floor, she stopped and shuffled her foot up to it to be sure she didn't trip over something. She said many words in Spanish, her parents' language, and some English. On verbal request she pointed to the parts of her body without error. She still had some searching movements of her eyes, but she could at times focus both together quite well. At that time it was still felt that she would have to learn braille for reading.

Third Year (2-3).-- During this year her language became quite fluent, though entirely in Spanish. She became toilet trained, but refused to feed herself with a spoon. In other ways she was independent and would go alone to visit her grandmother in the house next door. The second child, a normal boy, was adopted the end of this year.

Fourth Year (3-4).-- In this year she started to learn English. Her Spanish language ability was the pride of the grandparents, for she was the only grandchild who would converse with them in Spanish. She was a sociable, enthusiastic child, and would work or play with complex items for long periods of time. She enjoyed books and stories. Toward the end of the year she accepted feeding herself with a spoon or fork.

Fifth Year (4-5).-- In this year she became apprehensive in new situations and was afraid of strangers. Loud noises frightened her. At 4 years and 9 months she was seen by the psychologists for more formal testing. She was extremely apprehensive, and the introduction of a new activity was sufficient to make her break into tears. Her father was present during the testing and tended to push her to accept and try to test items. He seemed to attempt to deny that she had any visual handicap at all. The psychologists felt that in many instances her failures seemed to be due to her extreme anxiety. On the Hayes-Binet test she achieved a score of 82, but it was felt that her actual potential was probably better than this score would indicate. On the Vineland Social Maturity Scale her score was 98.

The end of this year she was enrolled in a parochial kindergarten.

Sixth Year (5-6).-- At first she was very timid in school and cried a lot. Gradually she accepted the situation and came to like school.

Present Status (6 Years 3 Months). -- She is attending the first grade in a Catholic school. She walks to school alone, and takes her lunch. She can read from the regular primer and copies written material from the blackboard, and has finished the first arithmetic book. She speaks Spanish and English well. Socially she seems much more confident. It is anticipated that she will continue to do well in school, although she may have difficulty later on with books with small print. Her general health is excellent.

Case. 10.-- This boy was born June 6, 1954, nine weeks prematurely. His birth weight was 3 lb. 8oz. (1,590 gm.). His mother had pyelonephritis in the last three weeks of her pregnancy, and a previous child had been born prematurely. Her delivery was normal. The boy was diagnosed as having retrolental fibroplasia at 2 months of age. Though his mother thought he had some vision early in infancy, he had none when first seen and to date shows no evidence of vision. The first child in this family was also prematurely born, and also is blind as a result of retrolental fibroplasia. He is two years older than this boy. There is a younger child, a girl, born at term, who has normal vision. This boy had some physical difficulties in early infancy, primarily severe respiratory infection and pneumonia. In the past two years he has been in good health.

The mother of this boy was only 17 when her first son was born prematurely and was found to be blind. She was only 19 when this boy was born. She has never appeared well and complains of chronic fatigue. Despite her apparent ill health, she was indifferent toward medical care, even when this was urged on her, in an effort to prevent premature delivery of the second child. The family's financial means have been limited. The father works hard to support the family. The mother also works intermittently. The mother's seeming indifference and depressed attitude was a major source of frustration for all those who tried to work with her and to help her. Even when both boys were chronically ill with recurrent respiratory infections and had significant anemia, she remained apathetic toward medical care. Neverthe less her relationship to the children seemed to be very strong. Emotionally and socially, both the boys seemed to develop rapidly and with emotional strength. The frustration of working with this family made it difficult to see the positive contributions of both parents to these blind boys, but no one could deny they were there.

The maternal great-grandparents have played an active part in caring for the boys, and in aiding these parents. It is hard to evaluate their contribution.

First Year (0-1).-- This boy was first seen for a developmental examination at 25 weeks of age, or a corrected age of 16 weeks. He did everything easily at a 16 week-level, and many items at a 20-week level. The latter were pull to sit, with no head lag; prone, arms extended; precarious grasp of the cube; massed cubes, grasps one; squealing and pats the bottle while being fed. He was given a developmental age of 16 weeks, and a developmental quotient of 100. There was some consideration of scoring him higher than this.

At 7 months of age he was hospitalized with a diagnosis of pneumonia following a prolonged upper respiratory infection.

By 9 months of age he sat briefly without support, stood with hands held, held his own bottle, transferred objects from one hand to the other; and talked to his toys. He rubbed his eyes a great deal and would evert his eyelids. The intraocular tension in both eyes was said to be normal. He was kept in bed a great deal, but despite this seemed to develop well motor-wise.

Second Year (1-2).-- At 15 months he could crawl; sit well without support; pull to a

stand in a crib; walk with two hands held; play pat-a-cake. He related easily to people and enjoyed playing with his brother. However, he was very aggressive and would bite and pinch when he was thwarted. He always wanted his brother's toys.

He was seen for a play evaluation at 20 months of age. He walked everywhere holding onto furniture. He vocalized a great deal, using words and jargon. His vocabularly was about 20 words. His general manipulation of toys was good and he showed a great deal of curiosity. He was considered to be doing reasonably well. No abnormal neurological findings were noted. His head circumference was 46 cm. His mother compared him unfavorably with his older brother, who she thought developed more rapidly and was easier to manage.

Third Year (2-3).-- At 25 months of age he started to walk alone and began to finger feed himself. He was seen for psychological testing at 28 months of age. A Vineland Social Maturity Test was done at that time and a score of 104 was given. By 30 months he was talking in phrases and indicated his toilet needs, but his mother did not follow through with toilet training. His language was well developed by 36 months, and his motor development was very good.

Fourth Year (3-4).-- At 40 months of age his brother started school and he was home alone. Generally he stayed with his great-grandmother while his mother worked. He became less "stubborn" after his brother started school. He accepted toilet training, and his aggression decreased. He began to chatter constantly.

Present Status (4 Years).--At 4 years of age he was seen for psychological testing. His score on the Hayes-Binet test was 105, and on the Vineland Social Maturity Scale 115. His head circumference is 49 cm.

He is a very capable boy. He uses his hands well, learns to manipulate objects readily, and will follow directions. He is at ease with strangers and talks freely with them. His adjustment to all new situations is remarkable. His general health is good.

It is anticipated that he will attend the public school for the blind, where his brother attends. These parents were not particularly interested in a school program integrated with sighted children. They are very well satisfied with the older boy's school experience. This boy should do well in school.

SUMMARY

Ten prematurely born children with normal vision and ten prematurely born children who were blind as the result of retrolental fibroplasia were evaluated in the first year of life by means of the Gesell infant development test. All were considered to be developmentally normal at that time, although one of the blind children was found to have a severe hearing deficit in addition to his blindness. This article is concerned with the further development of these children in the subsequent four to five years.

Seven of the premature infants with normal vision were available for retesting by the Stanford-Binet intelligence test and the Vineland Social Maturity Scale and all were normal at 3 to 6 years of age.

Six of the blind children are doing very well as determined by biographical reports of their play activities and social responses and also by psychological testing. Two of these children have acquired a small amount of useful vision in one eye, and a third child has useful vision in both eyes and can read large print with glasses. The remaining three are essentially totally blind. The child with the double handicap of deafness and blindness is progressing surprisingly well and is believed to be normal in his mental potential. How-

ever, it is impossible to effectively evaluate his abilities. He has acquired useful vision in one eye that helps him considerably.

Three of the children are functioning at a mentally retarded level. However, all show some signs of reasonably normal development. All three have withdrawn considerably from social contact and have other behavioral difficulties suggestive of severe emotional problems. It was concluded that they probably have normal mental potential that is not manifest because of severe emotional problems. Two are receiving psychiatric help and have shown some improvement.

Neurological examinations did not reveal any abnormalities in any of the children, except the deaf child. Electroencephalograms were done on six of the children and were not diagnostically significant, though two were suggestively abnormal.

A tabulation of the development of four self-help items--(1) walking without support; (2) feeding self with spoon; (3) talking in sentences; (4) toilet training-- revealed some delay in the development of all except talking. This pertains to the six normal children and those with some useful vision were not advanced over those without vision on these items. The three functionally retarded children did almost as well as the other children with respect to walking but had not had success with any of the other items by age 4.

It was concluded that developmental examination in the first year of life is a valuable adjunct in the evaluation of prematurely born blind children. This is of particular value to the parents of blind children and the professional workers who aid the parents.

The biographical summaries reveal some of the details of the development of the individual children and the family problems associated with rearing a blind child.

We are grateful to the staff of the Field Service for Blind Preschool Children of the California School for the Blind, especially Mrs. Margery Cutsforth, Mrs. Elaine Kapanen, Mrs. Dorcus Douglass, and Miss Claire Jackson, who is now with the Dallas Services for Blind Children, for their continuous cooperation and very carefully recorded observations. We also wish to express our appreciation to the staff of the Holy Family Adoption Service for their help and cooperation.

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COMMUNICATION VIA THE KINESTHETIC AND TACTILE SENSES

by

James Charles Bliss

EDITOR'S NOTE:

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ABSTRACT

A general model for a sensory-aid communication system is proposed which contains a source, sensor, processor, display, sensor channels, and user. The coding, display, and control aspects of this model are discussed in relation to communication via the tactile and kinesthetic senses. Two hypothetical methods of obtaining high information rates are proposed. In one method, the system recodes the source messages into approximately equal information units; and in the second method, the user recodes the messages into equal information units.

Four experiments that investigate the possibility of using passive movement to transmit information are described. In one experiment, discriminability of position-pulses of various widths and heights applied to the subject's index finger was measured. In the second set of experiments position-pulses of various directions were applied to the subject's index finger. It was found that movements in the $\pm x, \pm y$, and $\pm z$ directions of about 3/16 inch can be rapidly discriminated. In the third experiment, the ability of subjects to localize pairs of fingers which are moved simultaneously was investigated. In the fourth experiment, the visual and the kinesthetic-tactile senses were compared in a task of recognizing 1 x 6 matrix patterns.

A kinesthetic-tactile display device for English text is described. This display device consists of eight finger rests, each of which can move in 26 directions in three-dimensional space. A method of programming this device to present information was investigated in detail. The subject's fingers are moved corresponding to the way he would actively move them if he were typing. An information transmission rate of 4.5 bits/sec was obtained with the "typewriter" display.

TABLE OF CONTENTS

GENERAL CONSIDERATIONS ON KINESTHETIC

AND TACTILE COMMUNICATIONS

This chapter is concerned with the system problems in tactile and kinesthetic communications. Coding and display are two of the major problems which must be solved in order to fully utilize the information-carrying abilities of the tactile and kinesthetic senses. Moreover, the best code and display may result in these senses being used in an atypical fashion, which would require a difficult learning process.

The System Model. In order to discuss various problems concerning information transmission to the human, we will first postulate a general system model for a sensory aid. This model is shown in Fig. 2.1-1.

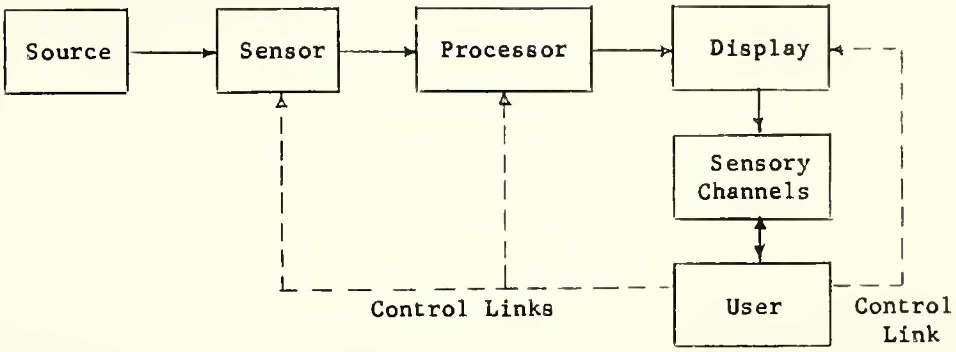

Fig. 2.1-1

A COMMUNICATION SYSTEM MODEL OF A SENSORY AID

The block labeled "source" represents any place from which information is to be obtained, such as the visual world or a book. The role of the "sensor" is to acquire information from the source and transduce it into a form suitable for processing.

The "processor" may perform some of the following functions: storage, information filtering, recognition, and encoding. Generally, storage is needed because the rate at which the sensor acquires information is not instantaneously equal to the rate at which the user takes in information. Furthermore, all of the information obtained by the sensor may not be of interest to the user. Therefore, an information filter which rejects unnecessary information may be included in the processor. Also, the processor may perform a recognition function. This could consist of comparing the input signals with information in permanent storage and then identifying the input as being comprised of particular parts of this stored information. (If the processor does not perform the recognition function but, for example, simply translates light into tactile stimuli, then the sensory aid is a "direct translation" machine.) Finally, the processor encodes or translates the information into a form suitable for display to the user.

The "display" block represents the method by which the information is presented to the human. This display may be such that it must be actively scanned by the user, for example, as in braille; or it may require a passive role for the user, as in writing on the skin.

The human is divided into two blocks in this model: "sensory channels" and "user." The "sensory channels" block represents the sensory transformations which take place in the human body and the pathways over which the nerve impulses travel. The block labeled "user" represents a human who is trying to obtain information of interest to him from the source.

An important aspect of any sensory aid system is the control which the user may exert over the system. Consequently, the model of Fig. 2.1-1 includes control links from the user to the sensor, processor, and display. In this way, information can flow from the user to the system, so that the system can adapt itself or be programmed to satisfy the desires of the user.

<u>The Coding Problem.</u> The message space can be described (in the discrete case) by an n-dimensional tensor which represents the n-gram frequencies of an input sequence of messages. For example, the message sequence, $\ldots\ldots, m_{h,i-1}, m_{h,i}, \ldots\ldots$, where h specifies one of the x messages in the message space and the second subscript denotes the position of the message in the sequence, has digram frequencies which are given by a matrix of the form:

$$\begin{array}{c|ccc}
 & m_{1,i} & \cdots & m_{x,i} \\
\hline
m_{1,i-1} & P(m_{1,i}, m_{1,i-1}) & \cdots & P(m_{x,i}, m_{1,i-1}) \\
\vdots & \vdots & & \vdots \\
m_{x,i-1} & P(m_{1,i}, m_{x,i-1}) & \cdots & P(m_{x,i}, m_{x,i-1})
\end{array}$$

Specifically, Pratt,[4] and Bourne and Ford[1] give the monogram and digram frequencies for English. Also, information of this type about English structure is in the memory of humans, as evidenced by their ability to correct typographical errors.[5]

Given an information source with a message space as described above, the coding problem is to transform the source information into stimuli which will convey information of interest to the user <u>with an accuracy which satisfies his fidelity criteria</u>. The ability of the human to identify stimuli can be described by a "confusion" matrix of conditional probabilities that a particular response will result from a given stimulus. For example, if the input stimuli are denoted by a_j and the output responses are denoted by b_k, the "confusion" matrix for a memoryless stimulus-to-response channel is:

Response

$$\begin{array}{cc|ccc}
 & & b_1 & \cdots & b_x \\
\hline
\textbf{Stimulus} & a_1 & P(b_1|a_1) & \cdots & P(b_x|a_1) \\
 & \vdots & \vdots & & \vdots \\
 & a_x & P(b_1|a_x) & \cdots & P(b_x|a_x)
\end{array}$$

The encoding of the source may be simply a one-to-one mapping of source messages into sensory stimuli, or it may be more complex, such as the transformation of source message sequences into blocks of equal length and equal information. However, since sequential constraints between messages do not greatly influence human information rates, there is no real advantage in having the system remove sequential redundancy. Therefore, it may be desirable to have the encoder perform a one-to-one mapping between messages and sensory stimuli.

The Isomorphic Encoder. For the simple case of a one-to-one mapping between messages and sensory stimuli, and for binary message space with only first order (monogram) statistical constraints between messages, an encoding rule for maximizing the transmitted information $T(x:y)$ can be stated as follows: Transmit the most probable message most accurately. (However, it may be more reasonable in a given situation to use a criteria other than maximum $(Tx:y)$. For example, minimum probability of an error or minimum cost or risk are reasonable criteria for certain situations.)

However, if the source generates messages with digram statistical constraints, it is not known at present whether a general coding rule exists which maximizes $T(x:y)$. Nevertheless, a simple example* will show that the rule given above does not always result in maximum average transmitted information for the case of digram statistical constraints. Consider a binary message source in which the digram frequencies are:

	$m_{1,i}$	$m_{2,i}$
$m_{1,i-1}$	0.2	0.4
$m_{2,i-1}$	0.4	0.0

and a channel in which the confusion matrix is:

	b_1	b_2
a_1	0.8	0.2
a_2	0.5	0.5

Then assigning m_1 to a_1 and m_2 to a_2 results in an average transmitted information of 0.0328 bits/message, while assigning m_1 to a_2 and m_2 to a_1 results in 0.1442 bits/message. Therefore, sending the most probable symbol least accurately results in maximum information transmission for this case.

The Display Problem. After the information has been acquired and processed, it must be presented to the user. The display problem consists of presenting this information to the sensory channels in an optimum fashion. Since many kinesthetic and tactile sensations exist for coding information (for example, light pressure, deep pressure, vibration, texture, electric shock, real or synthetic tactual movement, kinesthetic movement, and direction of movement), the problem is complex.

There are two general guides that can be applied to the design of displays. The first is:

1. Transmitted information increases with the dimensionality of the observations, even though the differences in physical dimensions between stimuli are perfectly correlated with one another.

Thus the designer should select as many stimulus dimensions as practical. Then in the hyperspace formed by the dimensions which are perceptually orthogonal, the stimuli to be used should be selected so that they are as far apart as possible.

The second guide is:

2. The rate of continuous information transmission increases with the number of message alternatives.

Thus, if a high information rate is needed, a system should be designed so that the display can, at any instant of time or location in space, be in any one of a large number of different states.

* This example was pointed out by William B. Macurdy.

Active vs. Passive Role for the User. The importance of an active role on the part of the user, especially in the learning process, is implied by a series of experiments performed by Held.[3] In these experiments, it was demonstrated that compensation for various optically-produced rearrangements requires re-afferent stimulation. (Re-afferent stimulation is stimulation that changes as a consequence of the movements of the recipient organism.) In describing these experiments, Held[3] states:

> We have demonstrated the crucial rolè of re-afferent stimulation by comparing the outcome of exposing subjects to rearrangement under two conditions of movement with all other conditions kept as near to equivalence as possible. In the first or active condition, the subjects either locomote or simply move a limb. In the second or passive condition the subjects who remain alert, receptive, but passive, undergo movement, produced by the experimenter, equivalent to that of the active condition. The active subjects almost invariably compensate for the errors induced by rearrangement; the passive subjects do not.

There are two major ways in which the subject can obtain re-afferent stimulation when using a sensory aid. One method is by actively scanning the display. For example, a direct translation character reader might convert the light image of the characters into a virtual mechanical image. The subject would then identify the characters by active kinesthetic-tactile exploration.

The second method of incorporating means for re-afferent stimulation is through the control links shown in Fig. 2.1-1. For example, the user may be able to point the sensor of mobility aid in a particular direction, program the processor to look for particular properties in the visual field, and control the rate at which this information is displayed. Then by examining the changes in the display as a result of the control exerted by the user, the possibility exists that the user could learn to receive a high rate of information through complex atypical stimulation.

Two Hypothetical Methods for Obtaining High Information Rates. Based on these considerations of man's ability to receive and organize information, we are now in a position to propose methods for obtaining high information rates. Two methods will be discussed here -one in which the system recodes the source information into "equal information units," and the second in which the user recodes the source into equal information units via the display and the control links. Both of these systems attempt to convert a source which generates information at a non-uniform rate into a constant information rate system.

Encoding by the System. This method is based on an analogy with language units which closely resemble perceptual units, such as stenography, stenotypy, Grade II braille, Japanese kana, and morphemes. These language forms have a more uniform information distribution among their basic units than the English alphabet. For example, Grade II braille contains 180 contractions (of the more frequent words and letter combinations in English), so that in the transformation from English letters to braille cells there is a marked increase in the uniformity of the distribution of information persymbol. Fig. 2.5-1 illustrates a sensory aid communication system model with an output which is analogous to these language forms.

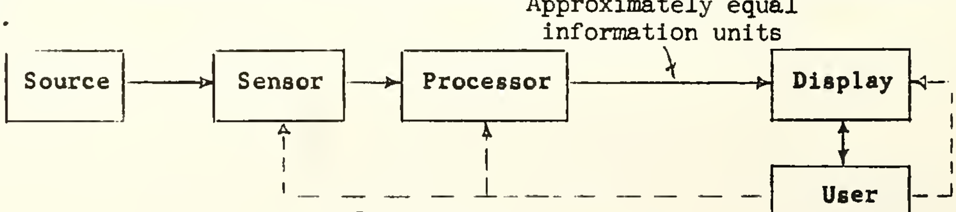

Fig. 2.5-1
MODEL FOR SOURCE ENCODING BY THE SYSTEM

In this type of system, the processor may require complex storage and encoding equipment, but the display system may be relatively simple. The storage holds information obtained from the source until at least one code unit of information is obtained. This unit is then transferred to the encoder, which makes the conversion to a form suitable for the display. The user's task is to acquire information from the display which is being supplied to him at an almost constant rate. His only control over the system may be to set the rate of information transmission.

However, this system has a disadvantage which could possibly limit its information rate, especially if the system is in widespread usage. Information units which are psychologically equal depend on the user's expectations or uncertainties, not on the true probability distributions. The user's expectations are certainly not constant in time or among different people. Therefore, unless the encoder has the ability to determine the user's expectations and then modify the code in an understandable fashion, it can at best only approximate a constant information rate. For example, Grade II braille only approximates a constant amount of information per cell in the interest of having a standard code with some degree of permanence.

Encoding by the Subject. The second hypothetical method for obtaining a high information rate is analogous to visual reading. When a person reads, his eyes move in saccadic jumps to various fixation points. The length of these jumps and the time spent at each fixation point varies from jump to jump.

It is suggested by Cherry[2] that in reading one purpose of these saccadic eye movements is to group the printed letters and words into more or less equal information blocks. In this way, fairly constant rate of perceptual information intake is obtained, even though individual letters and words vary greatly in the information they carry. In fact, the reason written language evolved into a form in which equal lengths do not carry equal information may be because the spatial aspect of vision is suited to grouping information into equal units, thus permitting word length to be another stimulus dimension for coding.

Fig. 2.5-2 represents a model of a sensory communication system which is analogous to visual reading in that equal information encoding is done by the user.

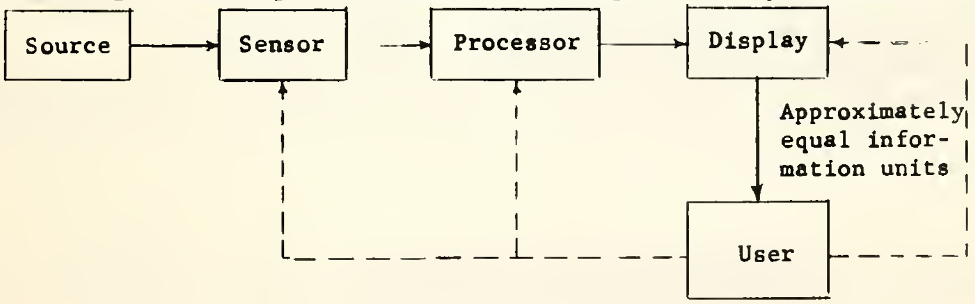

Fig. 2.5-2

MODEL FOR SOURCE ENCODING BY THE USER

In this model, the storage and encoding equipment in the processor is likely to be very simple, but the display may be quite complex. While the information is displayed with its original redundancy, it must be displayed in such a way that the user can easily group and organize the information to obtain a fairly constant rate of perceptual information intake. This requires a spatial aspect of the stimulus so that the user can "see" more than one place at a time. While the kinesthetic and tactile senses have a spatial aspect, achieving a display in which the subject can "see" a sizeable block of data at once, and divide this into equal uncertainty units, is a difficult problem.

However, the great advantage of this system over the system in which the encoding is done automatically is that the true expectations are used in the encoding instead of only an approximation.

Summary. In this chapter, a general model of a sensory aid communication system is proposed. The coding problem and the display problem are discussed in terms of this model. A coding procedure is presented for the case of monogram statistical constraints between a sequence of messages from a binary source. This coding procedure is based on the rule: Transmit the most probable message most accurately. However, if the message sequence has higher order statistical constraints, this rule does not always result in maximum information transmission. Two guides for designing or assessing a display are presented. These are:

1. Information transmission rate increases with the dimensionality of the observations.
2. Information transmission rate increases with the number of message alternatives.

The importance of an active role on the part of the user, so that there is the possibility of stimulation that changes as a result of the user's movements, are discussed. It is suggested that this re-afferent stimulation may be necessary in order for the subject ever to learn to use a sensory aid with a high information rate.

Two hypothetical methods for obtaining high information rates are presented. In one method, the system recodes the source information into equal information units; and in the other method, the user recodes the source information into equal information units. While the first method may be simpler to build, it can at best only approximate a constant information rate. The display for the second method may be complex, but in principle the optimum transmission rate should be obtainable with this system.

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SOME PSYCHOPHYSICAL EXPERIMENTS

One of the major problems in sensory communication system design is the selection of a suitable stimulus set. This set should consist of stimuli which are easily distinguishable, not painful, and not fatigable. In order to make an intelligent design, basic data are needed on the properties and characteristics of the sensory modalities to be stimulated. Some data can be found in the literature on the tactile and kinesthetic senses; however, much desirable information is notably lacking. In this chapter, some psychophysical experiments will be described which are pertinent to the problem of communication via the kinesthetic-tactile senses.

For information transmission by passive movement, there are several advantages to applying the stimuli to the hand. The hand is one of the most sensitive parts of the

body; it has many degrees of freedom, and its size is such as to require equipment of moderate size and power. A basic finger movement which might be used in a display device to convey discrete information is a position-pulse. In sec. 1 some experiments are described which indicate human abilities in discriminating between position-pulses of different parameters.

Another aspect of passive movement that is attractive for coding information is direction. Our fingers can be moved in any direction in three-dimensional space, which permits considerable flexibility on the part of the display. In Sec. 2, some experiments are described which indicate some of the potentialities for using direction of passive movement for transmission of information.

Still another possible stimulus aspect for coding information via the kinesthetic-tactile senses in spatial location. An experiment on the ability to identify pairs of simultaneously stimulated fingers is described in Sec. 3.

In Sec. 4, an experiment is described which compares the visual and kinesthetic-tactile senses in a simple pattern recognition task.

1. Discriminatory Thresholds for the Sense of Touch. In these experiments, a servo-control system was used for the application of a position-pulse to the subject's finger. The control system block diagram is shown in Fig. 3.1-1. Fig. 3.1-2 shows the parameters of the position-pulse, some of which were varied to determine discrimination thresholds for pulse height and pulse width, distinguishability of changes in pulse height and pulse width, and the effect of motion in different directions. The thresholds were measured by a frequency method,[5] according to which five stimuli, distributed over the range from the rarely noticeable difference to the almost always noticeable difference, were presented repeatedly to the subject in random order. In each trial, the subject was presented with a standard stimulus and then with a comparison stimulus. The subject's response indicated whether the comparison stimulus was greater or less than the standard.

Quantities calculated from these data are shown in Table 3.1-1. The probable error is equal to the difference that is noticed 50% of the time - the difference limen (DL). Weber's ratio was computed by dividing the DL by the standard stimulus (St). In experiments 1, 2, 3, and 4, the pulse height DL was measured for four different subjects. Roughly, it was found that a difference of less than 0.002 inch out of a total movement of 0.025 inch, in which the duration of the pulse was approximately 100 msec and the rise time was approximately 15 msec, could be detected. Subject 4 showed some improvement throughout the tests, presumably because he had more practice than the others.

In experiments 5, 6, and 7, the pulse height DL was measured for three values of pulse width. The purpose of these experiments was to determine whether the duration of the pulse has an appreciable influence on the DL for pulse height. While the DL obtained with the 90 msec pulse was the smallest, the differences in DL were only slight.

In experiments 8, 9, and 10, the pulse height DL was measured for three different finger positions. A sidewise motion with the knuckle bent (position 2) gave a larger DL than either an up-and-down motion with the knuckle bent (position 3) or an up-and-down motion with the finger extended (position 1).

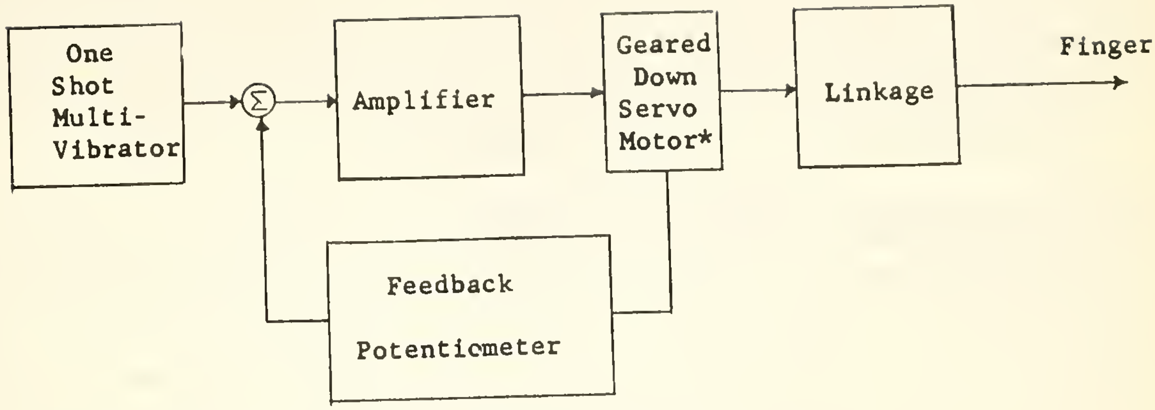
A single experiment was conducted to determine Weber's ratio for pulse-duration discrimination. This experiment gave a DL of approximately 29 msec out of 160 msec, or a Weber's ratio of 0.18. This result is in good agreement with Vierordt[3] who found that the Weber fraction for time durations less than 0.5 seconds was about 18%.

Table 3.1-1

RESULTS OF TOUCH DISCRIMINATION EXPERIMENTS

Experiment Number	1	2	3	4	5	6	7	8	9	10
Subject	1	2	3	4	4	4	4	4	4	4
Pulse Duration	68.8	68.8	110	110	90	50	200	95	95	95
Position	1	1	1	1	1	1	1	2	3	1
St	27.6	27.6	22.5	22.5	27.7	27.7	27.7	29	29	29
DL	2.27	1.79	1.99	1.80	1.46	1.62	1.64	2.36	1.23	1.34
Weber's Ratio	0.082	0.065	0.089	0.080	0.053	0.059	0.059	0.081	0.042	0.046

Note: All times are in msec, and all distances in mils.



* Servo motor: Diehl: 4 watts, 115V, 5.0 in oz.
FPE 25-11, 3600 rpm, 60 cps, 2 ϕ, 2 p
rotor inertia 0.077 in^2 oz.

Fig. 3.1-1

BLOCK DIAGRAM OF CONTROL SYSTEM USED IN PULSE DISCRIMINATION EXPERIMENTS

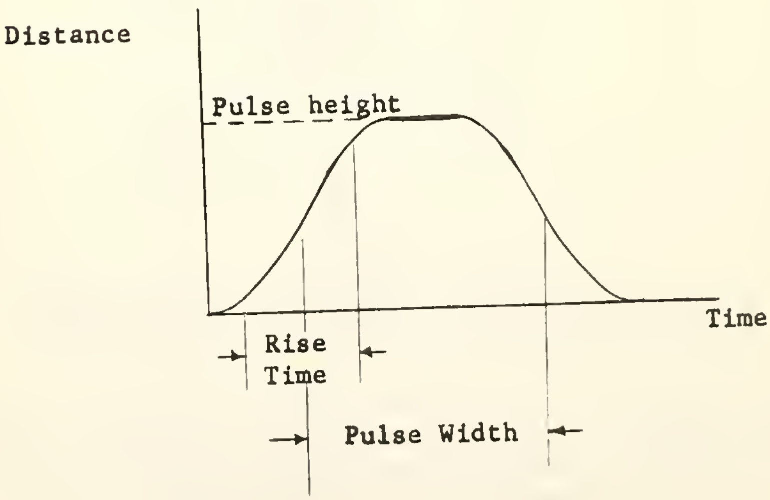


Fig. 3.1-2

PARAMETERS OF A POSITION-PULSE

Finally, a single experiment was conducted with subject 4 to determine how well a change in pulse height can be distinguished from a change in pulse duration. Five pulse durations (55, 75, 115, and 135 msec) and five pulse heights (24, 27, 29, 31, and 36 x 10^{-3} inches) were used. The subject was given a standard pulse (95 msec, 0.031 inches) and then a comparison pulse. He was asked to report whether the comparison pulse was greater or less in height, or longer or shorter in time. Only one of these four answers was permitted. From the results of this experiment, it appears that the subject can accurately detect a change in the area or energy of the pulse, but he cannot discriminate between a change in pulse height and a change in pulse duration. This result is similar to Bunsen-Roscoe Law for vision which states that, below a "critical duration," intensity times time equals a constant in threshold measurements.

2. Detection of Direction of Passive Finger Movements. A device similar to a typewriter key, except that it is capable of movement in any one of seven possible directions, was used in these experiments. This device is powered by three rotary solenoids (Ledex Size 2E Cat. No. A-35234-032). These solenoids are oriented so that their shafts are mutually perpendicular. Upon each shaft is fastened a slotted plate. The finger rest shaft fits into these three slots. Thus when any solenoid is activated, its shaft rotates, moving the finger rest in a direction perpendicular to the axis of shaft rotation. Any combination of the three solenoids can be activated simultaneously, so that the device can be in any one of $2^3 = 8$ possible states. The total motion is slightly less than 3/16 inch in all cases. Fig. 3.2-1 shows the possible directions that can be obtained. The index finger of the subject's right hand was placed lightly on the finger rest in a position similar to that used by a typist. Direction 4 was in a horizontal plane away from the body.

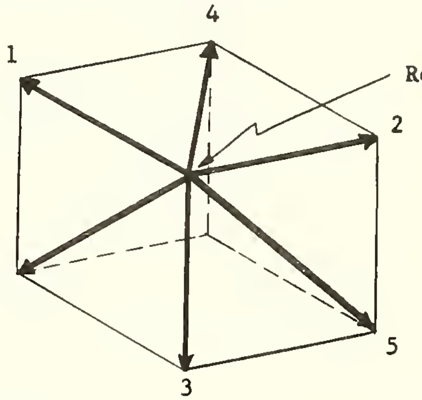


Fig. 3.2-1

THE SIX DIRECTIONS OF MOVEMENT OF THE FINGER REST
(Directions 1, 2, and 3 are mutually perpendicular.)

Two sets of experiments were performed with this apparatus. In the first set, a single movement consisting of apulse of position which lasted approximately 70 msec was presented to the subject. The subject responded by reporting the perceived direction of the stimulus. There were approximately five seconds between trials.

The second set of experiments presented two movements to the subject in rapid succession. The rate of these movements was varied from 2.2 to 7.5 movements/sec. Each movement could be in one of six directions with equal probability.

If we let:

n_{ij} = the number of times y_j was the response to the stimulus x_i and

N_i = the total number of times x_i was the stimulus, then

$P'(y_j|x_i)$ = the estimated value of $P(y_j|x_i) = \frac{n_{ij}}{N_i}$.

On this basis, the following confusion matrices of $P'(y_j|x_i)$ values were obtained for the different sets of stimuli.

A. Possible stimulus directions: 1, 2, or 3

	y_1	y_2	y_3
x_1	1	0	0
x_2	0	1	0
x_3	0	0	1

Number of trials: 46, Number correct: 46

B. Possible stimulus directions: 1, 2, 5, or 6

	y_1	y_2	y_5	y_6
x_1	1.0	0	0	0
x_2	0.04	0.96	0	0
x_5	0	0	0.82	0.18
x_6	0	0	0.44	0.56

Number of trials: 96, Number of correct: 81

C. Possible stimulus directions: 1, 2, 3, 4, or 5

	y_1	y_2	y_4	y_3	y_5
x_1	0.91	0.02	0.07	0	0
x_2	0	0.68	0.26	0	0.06
x_4	0	0.26	0.70	0.02	0.02
x_3	0	0	0.02	0.67	0.31
x_5	0	0	0	0.17	0.83

Number of trials: 284, Number correct: 213

D. Possible stimulus directions: 1, 2, 3, 4, 5, or 6

	y_1	y_2	y_4	y_3	y_5	y_6
x_1	0.88	0.10	0.02	0	0	0
x_2	0	0.93	0.07	0	0	0
x_4	0	0.40	0.58	0	0.02	0
x_3	0	0.02	0	0.58	0.27	0.12
x_5	0	0	0	0.11	0.70	0.19
x_6	0	0	0	0.46	0.21	0.33

Number of trials: 279, Number correct: 189

These matrices reveal that there were few, if any, mistakes between motions entirely in the horizontal plane and motions with a vertical component. Also, motions entirely in the horizontal plane were discriminated more accurately than motions with a vertical component.

The channel capacity and the probability of the input motions required to transmit at the channel capacity can be computed by means of the following formulas.[4]

$$C = \text{channel capacity} = \log \sum_{j=1}^{L} 2^{-\sum_{i=1}^{L} q_{ji} H(Y|x_i)}$$

$$P(x_k) = 2^{-C} \sum_{j=1}^{L} q_{kj}\, 2^{-\sum_{i=1}^{L} q_{ji} H(Y|x_i)}$$

where the q_{ji} are the elements of the inverse of the $P'(y_j|x_i)$ matrix and

$$H(Y|x_i) = -\sum_{j=1}^{L} P'(y_j|x_i) \log_2 P'(y_j|x_i)$$

The results of these computations for the matrices given above are shown in Table 3.2-1. These results show that for six possible stimulus directions the maximum rate of information transmission occurs for $P(x_3)$ and $P(x_4)$ very near zero.

TABLE 3.2-1

CHANNEL CAPACITIES AND OPTIMUM STIMULUS PROBABILITIES FOR THE CONFUSION MATRICES

Matrix	C bits/symbol	$P(x_1)$	$P(x_2)$	$P(x_3)$	$P(x_4)$	$P(x_5)$	$P(x_6)$
A	1.58	0.333	0.333	0.333	-	-	-
B	1.57	0.325	0.272	-	-	0.258	0.145
C	1.43	0.324	0.154	0.054	0.142	0.323	-
D	1.54	0.225	0.320	0.065	0.000	0.180	0.210

In the second set of experiments, two stimuli were presented to the subjects in rapid succession. Fig. 3.2-2 shows how the percentage of correct responses varied as a function of the number of movements per second. The $P'(y_j | x_i)$ matrix for a rate of 2.2 movements/sec was not appreciably different from matrix D in the first set of experiments. Thus two successive movements, a channel capacity of 3.4 bits/sec was obtained. The $P'(y_j | x_i)$ matrix obtained for a rate of 3.7 movements/sec gave 0.95 bits/symbol, or 3.52 bits/sec.

From these experiments, it appears that motions in the six directions ($\pm x, \pm y$, and $\pm z$) would be more accurately detected and hence give a higher information rate. A device capable of motions in these directions was built, using air pressure to activate Sylphon

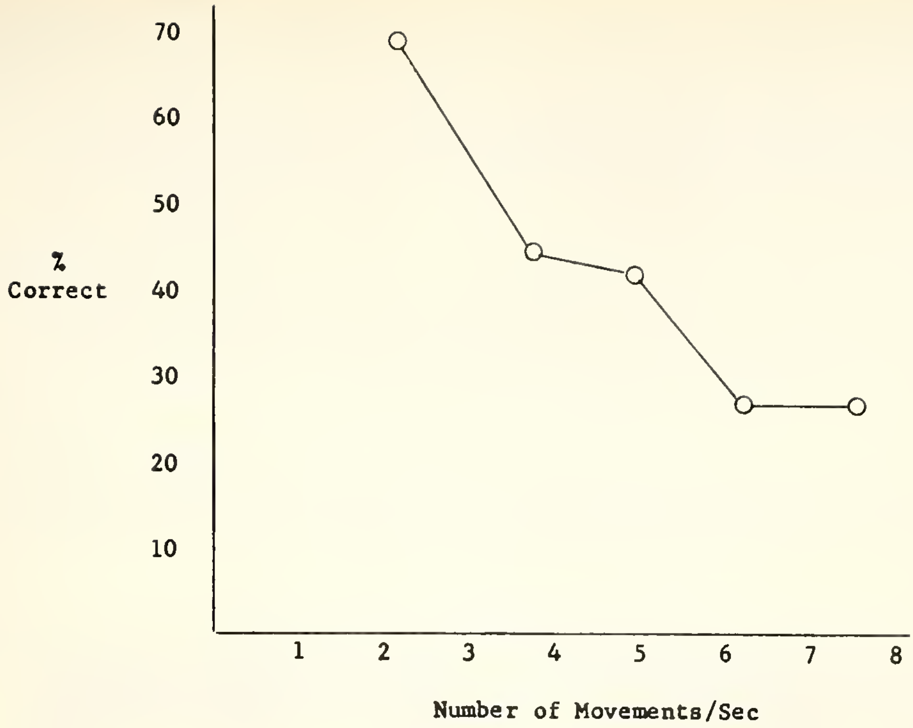


Fig. 3.2-2

PERCENTAGE OF CORRECT RESPONSES FOR A STIMULUS OF TWO MOVEMENTS AS A FUNCTION OF THE NUMBER OF MOVEMENTS/SEC

bellows that move the finger rest. The confusion matrix shown below was obtained from six untrained subjects and represents a sequence of three movements at a rate of 2.8 movements/sec. The information transmitted was 4.7 bits/sec, showing the expected increase.

		Response						
		x	-x	y	-y	z	-z	None
	x	0.83	0	0.04	0	0	0	0.13
	-x	0	0.88	0	0	0.06	0	0.06
Stimulus	y	0.07	0	0.70	0	0	0	0.23
	-y	0.10	0.03	0	0.63	0.07	0	0.17
	z	0.10	0	0.07	0	0.73	0.03	0.07
	-z	0.03	0	0.07	0.03	0	0.83	0.04

Number of observations: 180
Number correct: 138

The data presented above give some indications about capabilities of a human to discriminate between small movements of different amplitudes, time durations, and directions of his fingers. However, these experiments were only exploratory in nature, using a small number of subjects in a limited number of trials. Much more research needs to be done in this area before the performance of a human can be predicted from theory. These experiments have been done only with passive motion - many other dimensions exist for coding information.

<u>3. Detection of Spatial Location by the Kinesthetic-Tactile Senses.</u> In complex multiple-finger stimulation, either the stimulation can be presented to all the fingers at once,

each finger can be stimulated in time sequence, or some combination of these two possibilities may be used. In order to make this choice, it is necessary to know how many spatial locations, simultaneously stimulated, can be correctly identified. Also, in designing a code using spatial location as a stimulus dimension, it is helpful to know relative distinguishability between different spatial locations. The experiment described in this section was aimed at determining some information about these questions.

A Finger Localization Experiment. Benton[2] found that with tactile stimulation, fewer localization errors were made on the thumb and little finger than on the inner fingers of the hand. He also found that when the task of finger localization is made more difficult by requiring the subject to identify not only the finger but also the side of the finger which had been touched, errors involving mislocalization of the touched side do not follow the general principal of a more accurate localization of the outer digits of the hand.

As an extension of Benton's work, the following experiment was designed to determine the ability of a subject to recognize which pair of his fingers was stimulated. Also of interest was how much interaction existed when each of the possible pairs of digits was stimulated.

The experiment performed consisted of simultaneously moving some pair of the subject's fingers in an up direction. Only six fingers were used in this experiment: the index, middle, and fourth fingers of each hand. The apparatus consists of eight finger rests, six of which can be moved in a vertical direction by Sylphon bellows according to a program punched on paper tape. The movements were at least 1/8 inch in all cases, which is well above threshold. A shield was placed so that the subject could not see his hands. Air pressure was on the bellows for 10 msec for each stimulation. Two subjects were used in the experiment.

The number of stimulus pairs presented to each subject was 120. The confusion matrix obtained from the experimental data is shown below. Each entry in this matrix is the number of times a particular stimulus-response pair was obtained.

		1	2	3	4	5	6
4th finger, left hand	1	78	1	1	0	0	0
3rd finger, left hand	2	4	64	11	0	1	0
2nd finger, left hand	3	0	7	73	0	0	0
2nd finger, right hand	4	0	0	0	70	10	0
3rd finger, right hand	5	0	0	0	4	70	6
4th finger, right hand	6	0	0	0	0	3	77

Two conclusions can be made from these data. They are:

1. Most errors in finger localization result from confusion between adjacent fingers on the same hand. Only one error was made in which the reported finger was on the hand opposite to the stimulated finger, and only one error was made in which the response indicated a finger on the same hand but not adjacent to the stimulated finger.

2. There were more errors involving the middle finger of each hand than any of the other four fingers used in the experiment. This result is similar to the error pattern found by Benton.[2]

From this experiment, it appears advisable to avoid (for sensory displays involving passive movement of the fingers) stimuli that differ only in that they occur on adjacent fingers of the hand.

4. A Comparison between the Kinesthetic-Tactile and Visual Senses in a Pattern Recognition Task. The fundamental problem in the development of sensory aids for the blind is to convey information available to the eye through other sense modalities. It is the space-character, however, which gives vision its unique utility; thus it is important to determine if other sense organs can even remotely approach the eye in its capacity to reveal spatial relations.

This section is a report of an experiment which the author and R.J. Massa conducted jointly. R.J. Massa was responsible for the visual part of the experiment, and the author was responsible for the kinesthetic-tactile part. Both parts are reported here for completeness.

Visual Experiment in Pattern Recognition. In the visual part of the experiment, 21 subjects were shown a sequence of 13 patterns, each consisting of a horizontal row of six black or white squares. The patterns were exposed for six discrete time durations ranging from 30 to 500 msec. The subjects responded by placing "x's" on the answer sheet in each position where a white element appeared. The patterns were exposed with white squares on a black surround. The ambient light level was therefore resonably constant, and the stimulus intensity well above threshold. Fig. 3.4-1 shows two sample patterns

1 1 0 1 1 0 Fig. 3.4-1 0 1 0 1 0 1

SAMPLE PATTERNS FOR THE VISUAL EXPERIMENT

Performance in this task was good. A combined error rate of 0.25% was obtained for all patterns and all times. (An error was arbitrarily defined as any mismarked square--mismarked either through omission of a correct response (miss) or an incorrect response (false alarm).) The percentage of error versus exposure time duration for all patterns and for the test group (three white squares out of six) is shown in Fig. 3.4-2. Fig.3.4-3 shows the relative number of errors made on each of the 13 test patterns. The ordinate scale is normalized to the number of errors on the pattern with the best response. Fig. 3.4-4 shows the distribution of errors with respect to the stimulus positions. The stimulus patterns were so arranged that the subjects would make approximately the same number of responses for each position for the whole experiment.

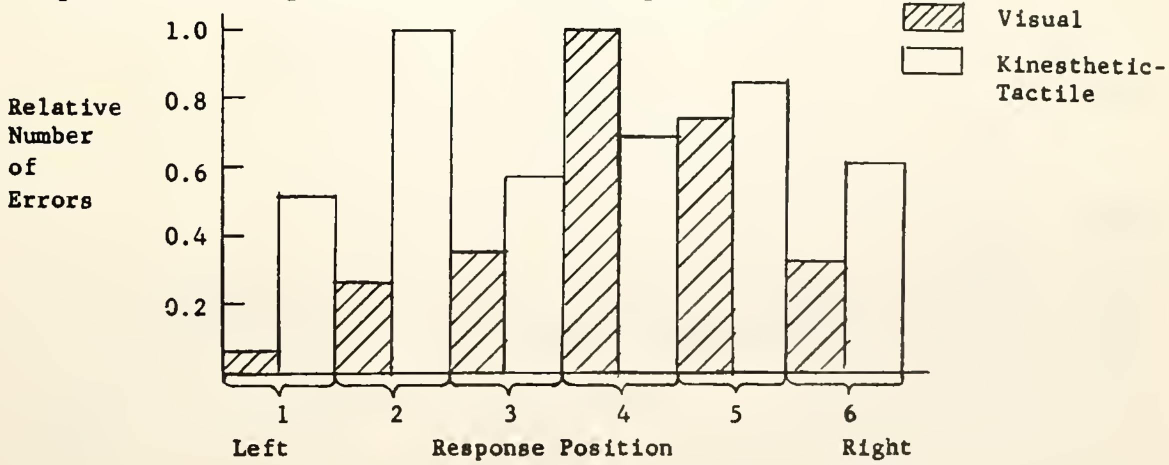


Fig. 3.4-4

RELATIVE NUMBER OF ERRORS VERSUS RESPONSE POSITION

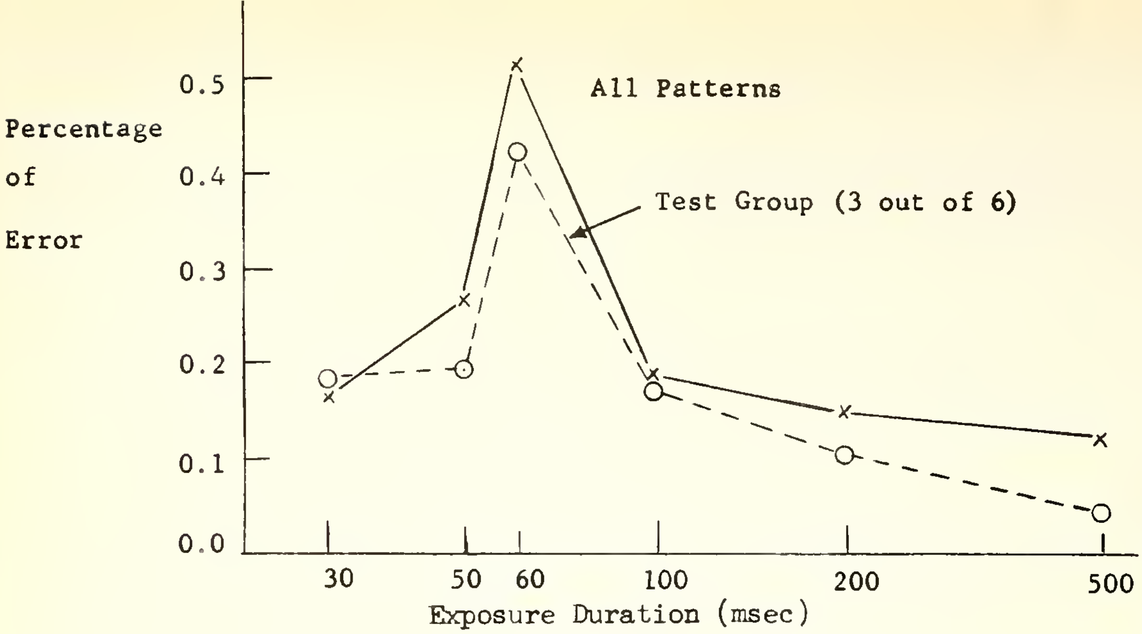


Fig. 3.4-2

PERCENTAGE OF ERROR VERSUS STIMULUS DURATION
IN THE VISUAL EXPERIMENT

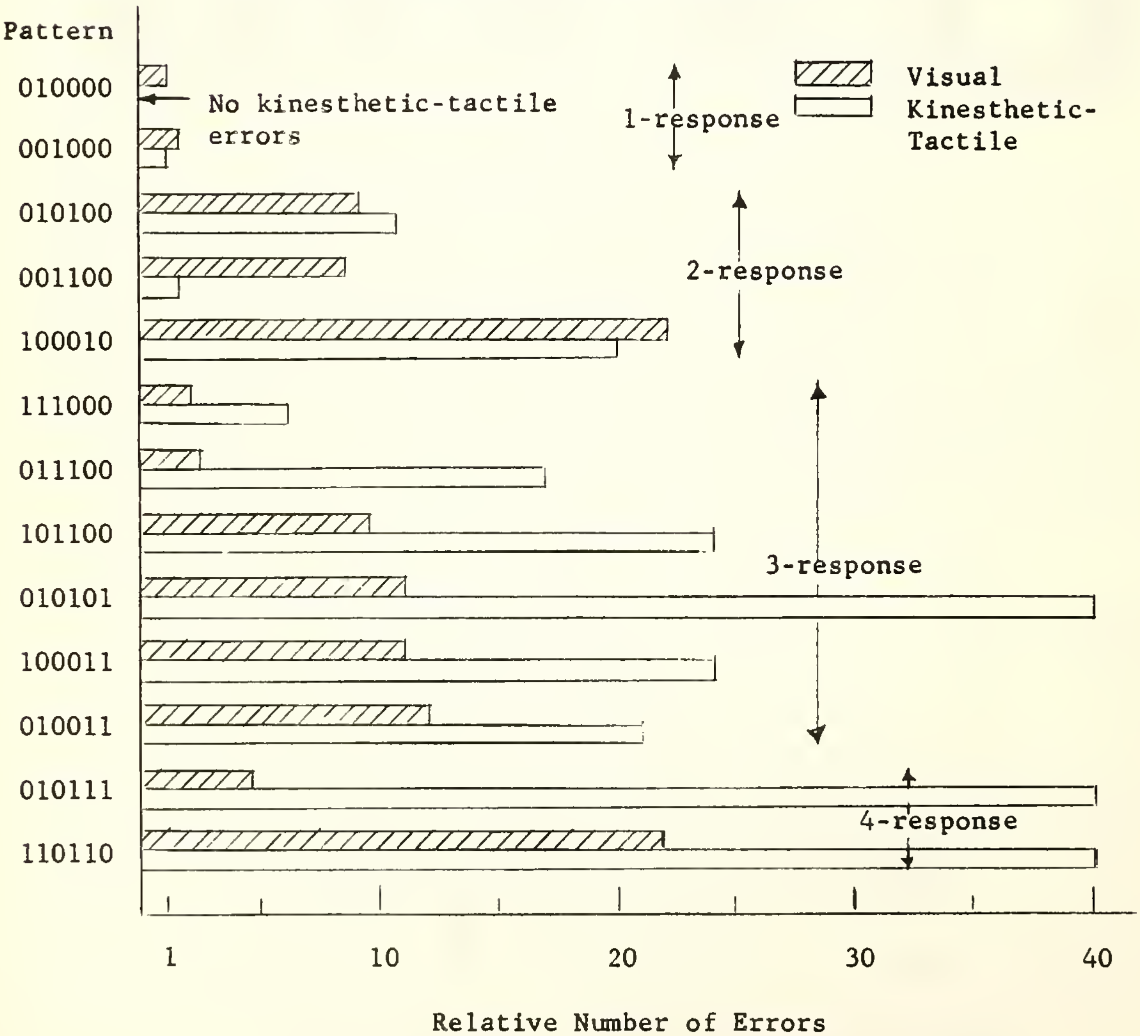


Fig. 3.4-3

DISTRIBUTION OF ERRORS AMONG PATTERNS

The most interesting feature of the experimental results is the peak in the error rate versus exposure duration curve in the vicinity of 60 msec exposure duration. This tendency is present in each individual pattern (at least when there is a sufficient number of errors to justify this statement). However, the experimenter (RJM) feels, by introspection, that the pattern exposures of approximately 60 msec duration produced the most pronounced afterimage. Furthermore, it is more difficult to stabilize the position of the afterimage in the visual field for exposures of this duration than for any other exposure used in the experiment. (This peak in the error rate was not noted in the kinesthetic-tactile experiment.)

For a 100 msec exposure of patterns from the test group, the subjects received information at a rate of less than 30 bits/sec, and their responses were essentially errorless (0.19%). The curve in Fig. 3.4-2 indicates that the subjects who took this test were capable of an information intake of 90 bits/sec with the same error rate for much shorter duration exposure times (30 msec). It should be noted that not all subjects behaved in this manner. Some of the 21 subjects made virtually no errors during the entire course of the experiment.

Fig. 3.4-3 illustrates how the errors were distributed for the patterns presented. Note that the positions of the white squares in the patterns are indicated by "1." Despite the fact that a pattern of two white squares and four black squares might be considered to be informationally equivalent to its complement (four white squares and two black squares), higher error rates are noted in which the subject's response is "four x's." In the 3-out-of-6 response patterns, the situation is different, since both complementary pairs require the same number of responses. Pattern No. 7 and Pattern No. 10 are complements, yet the error rate for No. 10 is three times higher. Examination of the patterns shows that the 3-in-a-row response pattern of No.7 is probably much simpler to encode than the separated response pattern of No. 10. Patterns No. 8 and No. 11 are also complements; the same error rate and the same general characteristics of the response pattern are noted. This phenomenon supports the general conclusion that informationally equivalent tasks are not always psychologically equivalent.

Referring again to Fig. 3.4-4, the fact that fewer errors are shown for the subjects in Positions 1 and 6 is in general agreement with published results.[1] The preponderance of errors in Position 4 despite the fact that the subjects' eyes were, in general, fixated in this position, is more difficult to explain. This result is in contrast with results published by Averbach and Coriell[1] in a study of short-term memory in vision. They report that when the subject is able to assimilate information for a fixed duration of time from a lineal array, he makes the fewest number of "recall" errors in the central positions.

Kinesthetic-Tactile Experiment in Pattern Recognition. The kinesthetic-tactile experiment consisted of simultaneously moving some combination of the subject's fingers. Only six fingers were used: the index, middle, and fourth fingers of each hand. The various combinations of finger movements corresponded to the 13 black-and-white 1x6 matrix patterns used in the visual part of the experiment. The apparatus consisted of eight finger rests, six of which were connected in this experiment. The six rests could be moved in the vertical direction by Sylphon bellows according to a program punched on paper tape. The movements were at 1/8 inch in all cases, which is well above threshold. A shield was placed in such a way that the subject could not see his hands during the experiment. On this shield, there was a diagram that gave number labels to the six fingers used in the experiment. The fingers were numbered from left to right, 1-6. Six discrete time durations, during which air pressure was on the bellows, were used to cover the range 10 msec - 500 msec. The subject responded orally by indicating the numbers of the fingers that were moved.

The combined error rate for all times and all patterns was 10.5%. (An error is defined as either reporting a finger movement that did not occur, or as failing to report a finger movement.) The percentage of error versus exposure time duration for the test group of patterns is shown in Fig. 3.4-5.

Fig. 3.4-4 shows the distribution of errors with respect to the finger stimulated. This distribution can be explained by assuming that most errors in finger localization are made between adjacent fingers on the same hand. This assumption agrees with the conclusions from the experiment described in Sec. 3. Thus the relatively low error rate obtained on fingers 3 and 4 in Fig. 3.4-4 is probably due to the fact that they are on different hands, and the low rate for fingers 1 and 6 probably results from the fact that these were the outside fingers in the experiment.

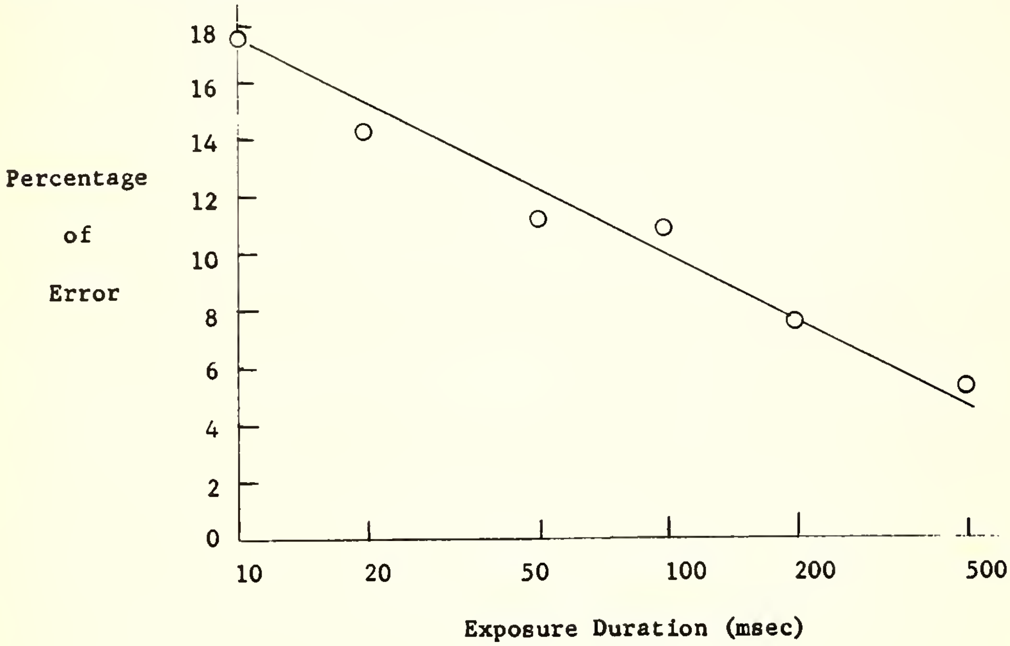


Fig. 3.4-5

PERCENTAGE OF ERROR VERSUS EXPOSURE DURATION FOR TEST PATTERNS IN THE KINESTHETIC-TACTILE EXPERIMENT

Fig. 3.4-3 shows the relative number of errors made on each of the 13 patterns. The percentage of error increased markedly with the number of fingers stimulated. It appears that complementary patterns with unequal numbers of fingers stimulated would give significantly different error rates. Patterns in which the stimulated fingers were adjacent, for example 111000, resulted in a much lower error rate than patterns in which alternate fingers were stimulated, for example 010101.

Comparison Between Visual and Kinesthetic-Tactile Experimental Results. Since the stimulus intensity for each modality was well above threshold intensities (although no attempt was made to equate the stimulus energy for each modality), it can be concluded that all subjects performed much better in this task with visual information intake. Error rates were greater than an order of magnitude higher for the kinesthetic-tactile experiment.

The assumption that error rates for complementary patterns should be equivalent is not upheld by the experimental results for either visual or kinesthetic-tactile stimulation. The reasons, however, are different for each sense modality. When the visual observer is asked to note the position of the white squares and report these positions, he does not appear to encode the pattern as a whole, but rather presumably to estimate the

distance between stimulus squares. This results in higher error rates on the complementary patterns with the greater distance between response positions (see Patterns No. 7 and No. 10 in Fig. 3.4-3).

With kinesthetic-tactile stimulation, complementary excitation (movement-no movement) appears to be even less useful as an encoding tool for the subject. This can be seen for the marked increase in error rate as one goes from 1-stimulus-out-of-6 to 4-stimuli-out-of-6(Fig. 3.4-3.).

In kinesthetic-tactile stimulation, the ability to dichotomize the stimulus because of the use of two separate hands, in contrast to visual stimulation, results in position errors for the two modalities which are significantly different in positions 3 and 4. In the visual display, the center positions are most often confused because the subject presumably measures distance from the ends. This conclusion is borne out in both the position error curve (Fig. 3.4-4) and the pattern error curve (Fig. 3.4-3).

A simple model of visual information transmission which assumes that performance should continue to improve as the stimulus duration is increased (because of greater stimulus energy at constant intensity) is not consistent with the observed data for the visual sense. The sudden increase in error rate when 60 msec exposures were used is most probably due to some "system" aspect of the visual process that is not present in the kinesthetic-tactile experiment.

The experiments presented above were exploratory. Relative values and trends were sought; the absolute values given should merely be considered as illustrative.

5. Summary. In this chapter, four kinds of psychophysical experiments on the kinesthetic-tactile senses are described. The objectives of these experiments were to explore the potentiality of using the kinesthetic-tactile senses for information transmission and to obtain data preliminary to the design of a kinesthetic-tactile display.

In the first type of experiment, position-pulses of various widths and heights were applied to the subject's index finger. The results of these experiments were:

1. A difference of less than 0.002 inch out of a total movement of 0.025 inch, in which the duration of the pulse was approximately 100 msec and the rise time was approximately 15 msec, could be detected 75% of the time.

2. In the range 50-200 msec, the pulse height difference limen is approximately independent of pulse width.

3. A sidewise motion with the knuckle bent gave a larger DL than either an up-and-down motion with the knuckle bent or an up-and-down motion with the finger extended.

4. A difference in pulse duration of roughly 29 msec out of 160 msec could be detected for pulses of equal amplitudes.

5. It was noted that for the pulse duration range 55-135 msec and the pulse height range 0.024 - 0.036 inch, an increase in area or energy of the pulse could be detected, but a change in pulse height could not be discriminated from a change in pulse width.

In the second set of experiments , position-pulses of various directions were applied to the subject's index finger. The results of this set of experiments were:

1. Errors were obtained among position-pulses entirely in the horizontal plane or among position-pulses with a vertical component, but almost no errors were obtained between the position-pulses entirely in the horizontal plane and the position-pulses with a vertical component.

2. Motions entirely in the horizontal plane were discriminated more accurately than motions with a vertical component.

3. An information transmission of about 1.5 bits/symbol out of a possible 2.6 bits/symbol was obtained for the presentation of a single movement of about 70 msec duration.

4. An information rate of 3.3 bits/sec was obtained for the presentation of a sequence of two stimuli at a rate of 2.2 movements/sec.

5. When the stimulus set was changed to motions in the $\pm x$, $\pm y$, and $\pm z$ directions, an information rate of 4.7 bits/sec was obtained for the presentation of a sequence of three movements at a rate of 2.8 movements/sec.

In the third experiment, pairs of the subject's fingers were moved simultaneously in an up-direction. The ability of the subject to recognize which fingers were moved when the up-motion occurred in 10 msec was measured. The results of this experiment were:

1. An error rate of about 12% was obtained.

2. Most errors resulted from confusion between adjacent fingers on the same hand.

3. There were more errors involving the middle finger on each hand than any of the other four fingers used in the experiment.

In the four set of experiments, a comparison was made between the visual and the kinesthetic-tactile senses in a task of recognition of 1 x 6 matrix patterns. The pattern exposure time was varied from 30 to 500 msec. The results of these two experiments were:

1. The error rate decreased monotonically as exposure time increased in the kinesthetic-tactile experiment. However, there was a peak in the corresponding error rate versus exposure time curve at about 60 msec in the visual experiment.

2. The over-all error rate for the kinesthetic-tactile experiment (10.5%) was greater than an order of magnitude higher than the error rate for the visual experiment (0.25%).

3. The distribution of kinesthetic-tactile position errors can be explained by assuming that most errors in finger localization are made between adjacent fingers on the same hand. The distribution of visual position errors can be explained by assuming the subject "estimates" the distance to a white square from the ends of the matrix.

4. Complementary patterns did not give the same error rates. This discrepancy was considerably greater for the kinesthetic-tactile experiment than for the visual experiment. Moreover, patterns in which the stimulated fingers were adjacent, for example 111000, resulted in a much lower error rate than patterns in which alternate fingers were stimulated, for example 010101.

6. References

1. E. Averbach, A.S. Coriell, "Short-Term Memory in Vision, "BSTJ, 60, (Jan., 1961), pp. 309-328.
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A KINESTHETIC-TACTILE COMMUNICATION SYSTEM

Theoretical considerations relevant to information transmission via the tactile and kinesthetic senses have been presented, and some psychophysical experiments with results important to the design of kinesthetic-tactile displays have been described. In the pages following, a specific kinesthetic-tactile communication system is described, and the experimental results obtained with this system are presented.

Even though the kinesthetic sense is a major information channel for the blind in both reading and mobility, few, if any, attempts have been made to utilize this sense directly in an instrumental information display. Consequently, the display system described in this chapter is novel in the respect that it is designed primarily to stimulate the kinesthetic sensory channel. However, it is undesirable from an information transmission standpoint to stimulate the kinesthetic sense without, at the same time, stimulating the tactile sense. Thus, in the system to be described, an attempt was made to use both the kinesthetic and tactile senses to advantage; no attempt was made to separate the effects and results with respect to either of these two sense modalities.

While the engineering problems involved in the development of a character recognition machine for the blind are difficult, they appear to be surmountable, so that new methods for conveying the character reader output information to the human may be needed soon. This kinesthetic-tactile display was designed to be primarily germane to the problem of transmitting printed text. However, slight modifications of this display would also make it applicable as an output for a speech recognition machine, and results obtained with this display suggest possibilities of using the kinesthetic sense for transmitting pictorial information.

For the following reasons, passive movement of the fingers was chosen as an information-carrying stimulus in this study:

1. The fingers have many degrees of freedom, offering numerous stimulus aspects for coding of complex information.
2. The fingers have a large representation in the cortex, and they are heavily innervated.
3. The fingers are among the easiest limbs to move because of their size.
4. For a character reader output, displays which require a primarily passive role to be played by the user have the advantage that less storage is required for real time operation.

5. The experiments previously described demonstrate the feasibility of using a position-pulse to code information.

Since a character recognition machine suitable for human reading is, at the present time, nonexistent and because of the availability of the TX-0 computer, perforated tape was used as the information-carrying medium in this study. Thus by using a medium that was compatible with the TX-0 computer, great flexibility for preparing complex stimulus patterns rapidly and conveniently was obtained.

Fig. 4-1 shows the complete system used for the studies described here in terms of the system model discussed earlier.

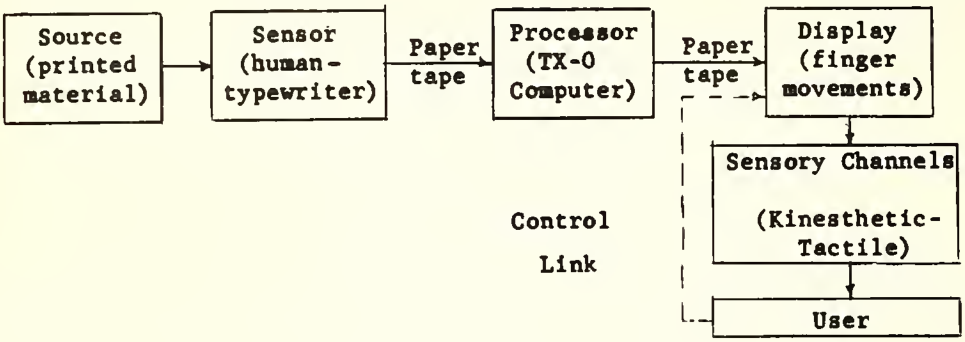

Fig. 4-1

THE KINESTHETIC-TACTILE COMMUNICATION SYSTEM

Design of the Display. The stimuli, passive finger movements, are obtained from a display consisting of finger rests which can be automatically positioned in three-dimensional space according to a prearranged program. The first attempt to implement this display idea resulted in a device powered by three rotary solenoids. The solenoid-powered finger stimulator has several disadvantages which are:

1. The characteristic "snap" action of the solenoids causes a jerk movement instead of a smooth motion.
2. Solenoids are inherently a one-directional device, which makes obtaining a plus and minus colinear movement complicated.
3. Solenoids are noisy, which is distracting.
4. Because of the inflexibility of the solenoid shaft, a sliding cam arrangement was used to obtain the perpendicular movement directions. "Play" in the finger rest is almost unavoidable with this type of arrangement.

An Air-Driven Finger Stimulator. Because of these disadvantages with solenoids, an all-pneumatic system was devised. In this system, a pneumatic paper tape reader (similar to a design by Mason and Troxel[4]) is used to valve air pressure to specific brass Sylphon bellows in a set of such bellows. These bellows, in turn, move the finger rests. Fig. 4.1-1 shows the design of one of the bellows assemblies which give plus and minus colinear movement.

In this assembly, the brass center piece is rigidly fastened by the mounting. The steel wire keeps the distance between the two brass end plates constant. The teflon plugs furnish a flexible, low-friction, air-tight bushing for the steel wire and also serve to reduce the inside volume of the bellows. Thus, air pressure applied to the (pull) bellows causes the rod to move to the left, and air pressure applied to the (push) bellows causes

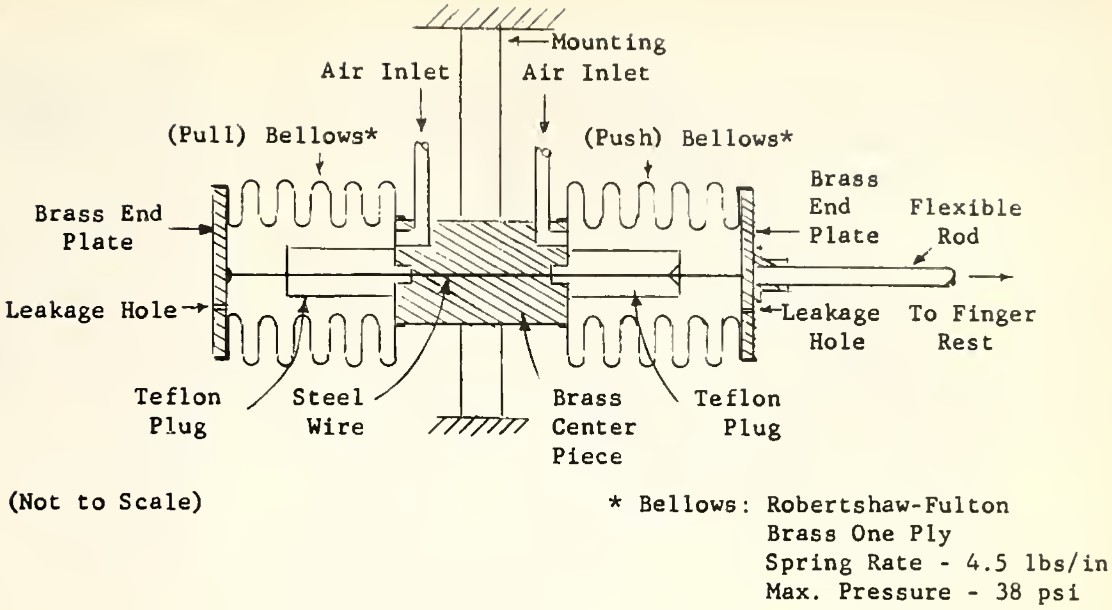

Fig. 4.1-1

PUSH-PULL BELLOWS ASSEMBLY

the rod to move to the right. If air pressure is applied to neither or both bellows, the rod remains in the center position. The small air leakage holes allow the rod to return to the center position after the air supply is valved off the bellows. Fig. 4.1-2 shows the basic system used for each finger rest. The three bellows assemblies have mutually perpendicular axes. With this basic unit, $3^3 = 27$ possible positions of the finger rest are possible.

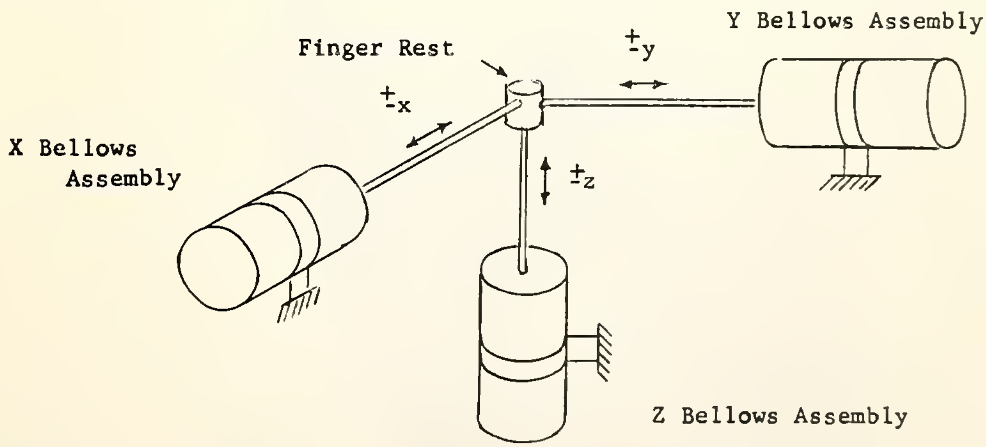

Fig. 4.1-2

SCHEMATIC DIAGRAM OF A SINGLE FINGER STIMULATOR

The final system with eight finger rests is shown in the photograph of Fig. 4.1-3. This display has $3^{24} = 2.824 \times 10^{11}$ possible states which gives considerable flexibility for experimentation with complex stimuli.

An attempt was made to enhance the tactile cues from this display by making half of

each finger rest have a different texture. Moreover, a ridge separates each finger rest half so that a tactile reference direction is given to aid the user in orientation.

A Pneumatic Paper Tape Reader. The pneumatic paper tape reader is actually two air valves, each consisting of a number of holes in two plexiglass plates. The paper tape is drawn between the plates, and alignment of a hole in the tape with holes in the plates permits air to flow. Thus the paper tape functions as the slide in the valves.

One of the two valves consists of a 6 x 8 matrix of holes, in which each hole is connected to one of the Sylphon bellows in the finger stimulator. The six rows of this matrix, corresponding to the hole positions 1-6 in seven-hole perforated paper tape, represent the +x, +y, + z, -x, -y, and -z movement directions, respectively. The eight columns of the matrix correspond to the eight finger rests of the stimulator. These eight columns are double-spaced on the plexiglass plates with respect to the paper tape spacing. Fig.4.1-4 shows a schematic drawing of the matrix valve.

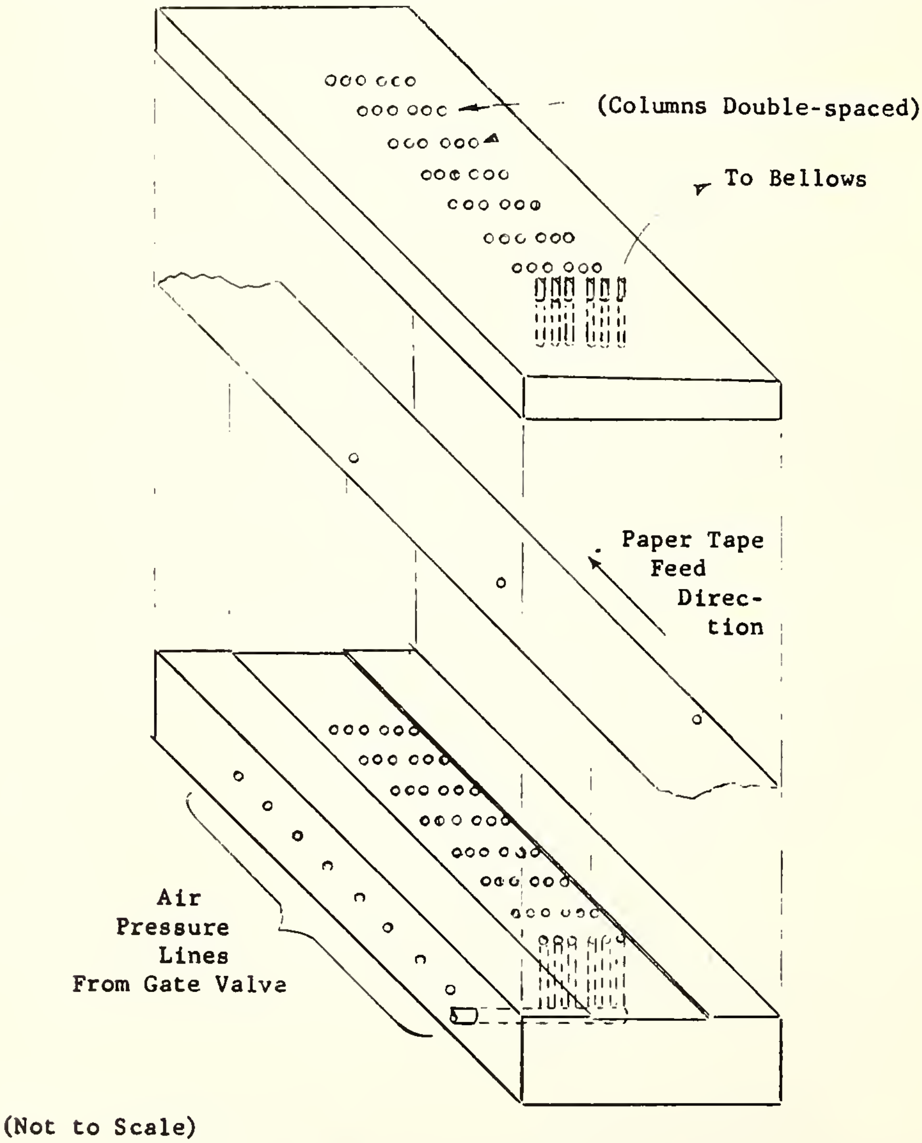

Fig. 4.1-4

6 x 8 MATRIX VALVE FOR PNEUMATIC PAPER TAPE READER

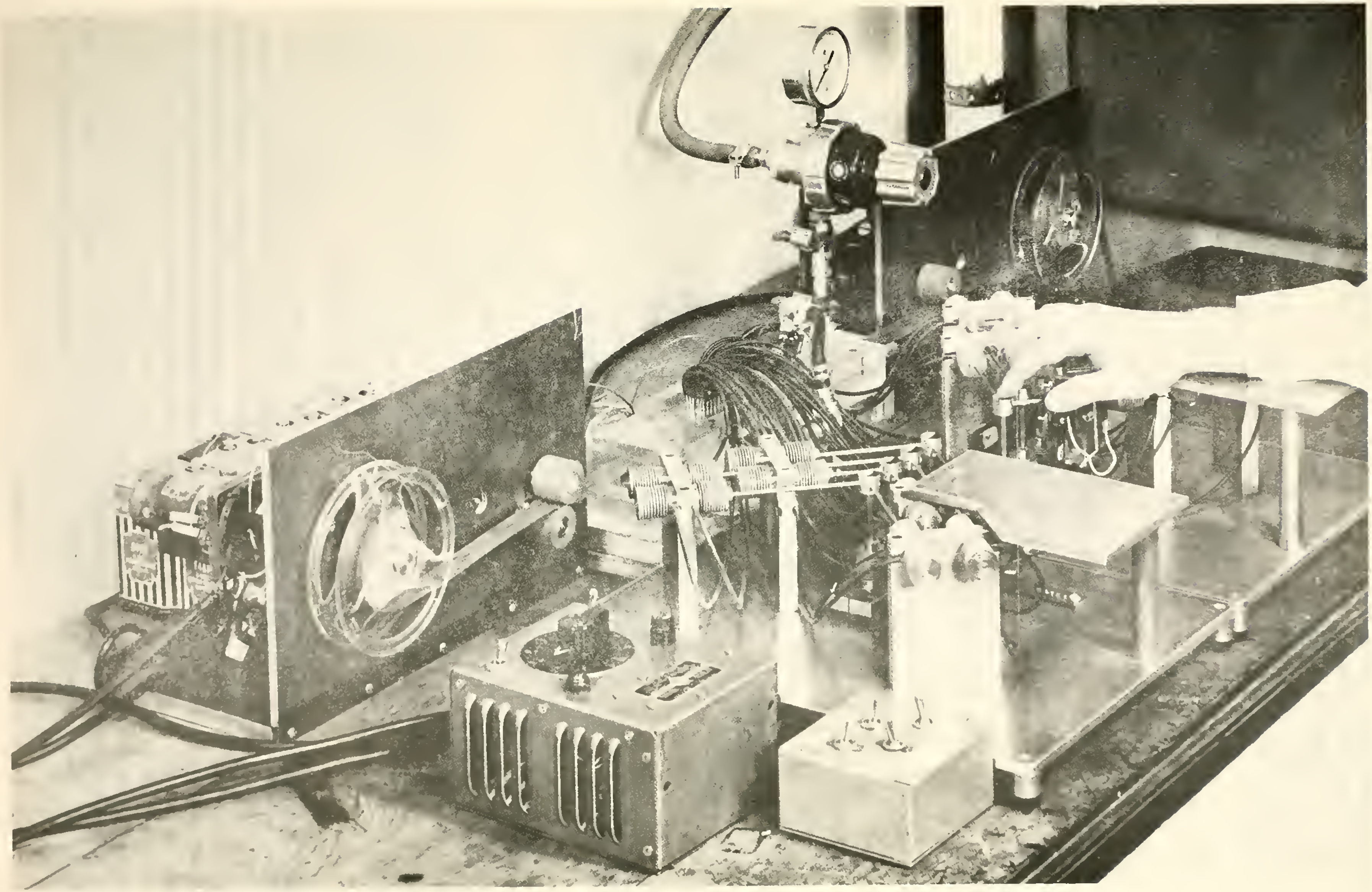

Fig. 4.1-3

AIR-DRIVEN FINGER STIMULATOR

The second valve "gates" air pressure onto the 6 x 8 matrix valve at a time that can be selected by the position of a hole in the seventh row of the paper tape. There are eight single-spaced holes in this gate valve, each of which gates one of the columns of the matrix valve. Fig. 4.1-5 shows a schematic drawing of the gate valve.

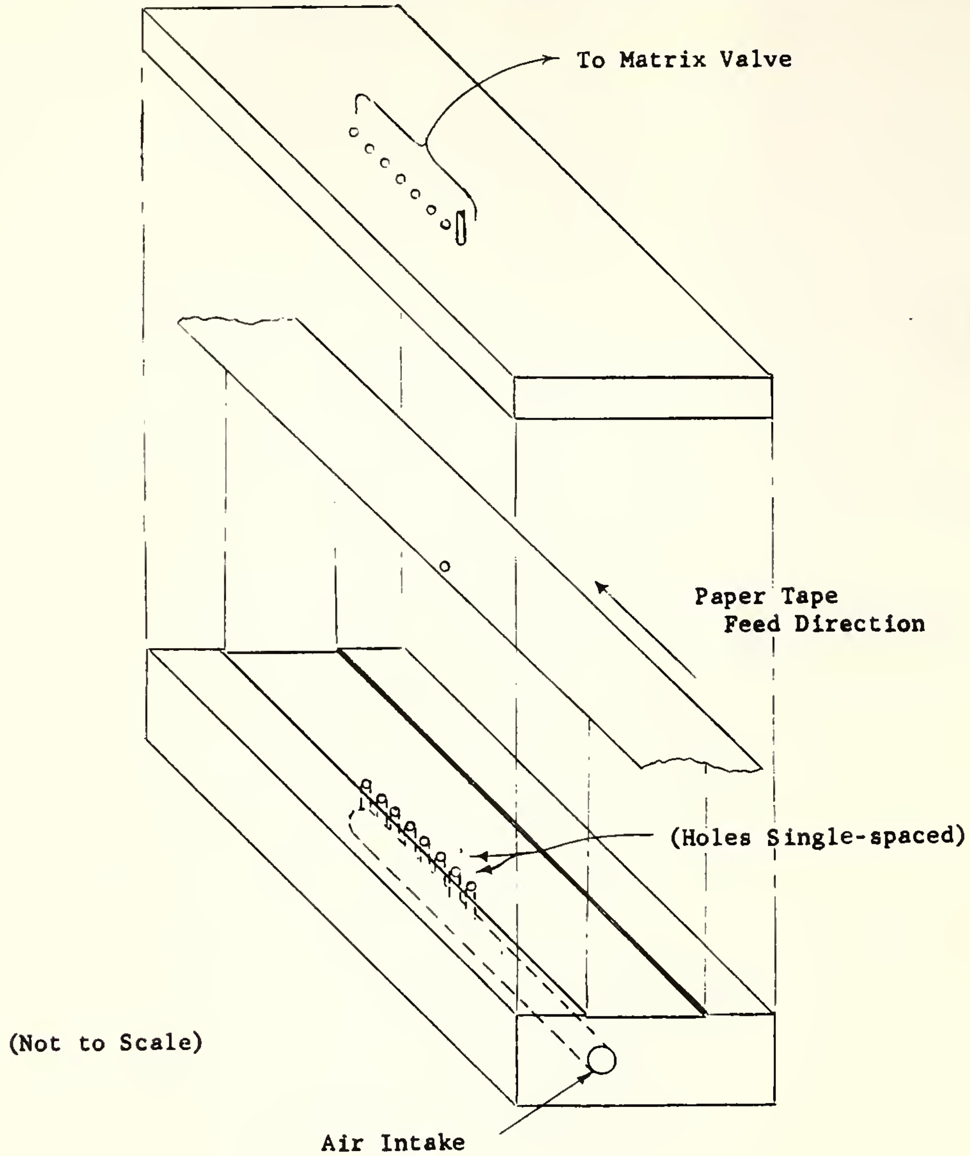

Fig. 4.1-5

GATE VALVE FOR PNEUMATIC PAPER TAPE READER

Some Presentations Possible with the Apparatus. There are many ways in which the pneumatic reader can be used to program information presentations on the finger stimulator. Since the display device can be in any one of 27 stimulus states at each finger location and at each instant of time, any possible presentation can be explained in terms of a location-time-stimulus coordinate system. The essential difference between the various presentations is the way in which the location aspect of the kinesthetic sense is utilized. In one presentation (traveling-wave), the location of the stimulus is merely used as an aid to memory; that is, the information is repeated at different locations, but the temporal order in which the locations are stimulated indicates the sequential order of the information. In another presentation (simultaneous), location is used directly as an information-carrying dimension.

The Simultaneous Presentation. An important example of a simultaneous presentation is the typewriter presentation. In the typewriter presentation, the subject's fingers are moved corresponding to the way he would actively move them if he were typing. A computer program is also given which converts paper tape punched on a Flexowriter to a tape that can be used in the pneumatic reader. In this program, finger movements in the vertical direction indicate the "home" keys (a,s,d,f,j,k,l); finger movements away from the body indicate the characters corresponding to the third row on a typewriter; and movements toward the body indicate the bottom row characters on a typewriter. In addition, the following modifications are used:

1. The "home" characters are indicated as follows: a-down, s-up, d-down, f-up, j-down, k-up, l-down. (Since more errors in localization result from confusion between adjacent fingers, this arrangement was chosen to make adjacent characters differ more.)
2. The space bar is indicated by a simultaneous movement in the x direction of the middle fingers on both hands.
3. The numbers, which are on the fourth row of a typewriter, are indicated by a simultaneous movement of the little finger on the hand opposite to that corresponding to the number being sent.
4. Lower case and upper case are indicated by the simultaneous movement of three fingers.

(EDITORS NOTE: "In addition to the typewriter presentation, the author outlined a variety of other displays which are possible with his device."

Typewriter Presentation Experiments. Three experiments were performed with the typewriter presentation discussed before. In one phase of experimentation, a blind subject[2] spent approximately two hours a week for two months practicing with the system. Secondly, the experiment was repeated with the typewriter presentation to give an objective comparison between the two displays. Finally, in order to determine a continuous information transmission rate with the typewriter presentation, a subject received symbols in random order and at various constant rates.

Learning the Typewriter Presentation. The typewriter presentation requires very little learning for someone who knows how to type. The different stimuli are all easily distinguishable, so that a subject can begin to read text material after a short training period. This training period is described below for the case of one subject.

In the first practice period, the subject became familiar with the machine and the stimuli for the letters, numbers, and symbols. Since she already knew how to type, the amount of learning required was slight. In the second practice period, a list of the most frequently used English words was presented, and by the end of the hour, these could all be recognized correctly at a rate of about 5 words/min. In the succeeding periods, the subject practiced with material from a fourth grade reader and the Reader's Digest. After about six one-hour sessions, the subject was reading this material at a rate of approximately 10 words/min.

At this point, some improvements were made on the system. Wind and rewind tape reels were added with controls that can be operated by the subject. These controls consist of micro-switches so placed that the subject can operate them with his thumbs. Pressing with the right thumb stops the display, and pressing with both thumbs reverses the tape. In this way, if a letter or word is missed, it can be repeated. Also, the on-off switch controlled with the right thumb serves as a rudimentary speed control.

With the addition of these controls, there was an almost immediate increase in word rate to about 15 words/min. However, due to the fact that the air pressure is on only 1/8 of the time in this display, the amplitude of motion begins to decrease rapidly at

speeds greater than 15 words/min. Therefore, this reading rate was probably a machine limitation, not a subject limitation.

Information Rate for the Typewriter Presentation. In this experiment, 30 symbols (the alphabet, comma, period, space, and upper case) were presented in random order to one subject. Sequences of these symbols were generated with the aid of a random number table so that all symbols were equally probable. Therefore, the self information of each symbol was 4.91 bits. The experimental stimuli consisted of six sequences of 130 symbols each, and the presentation rate of each sequence was chosen to cover the range from 0.5 to 1.5 letters/sec. The subject responded orally by naming the symbols as they were received.

Fig. 4.4-3 shows the results of this experiment. The information in the correct responses was calculated by means of the following formulas:

$$T = \frac{\%\ \text{correct}}{100} \times 4.91$$

$$T = \frac{\%\ \text{correct}}{100} \times 4.91 \times \text{Presentation Rate}$$

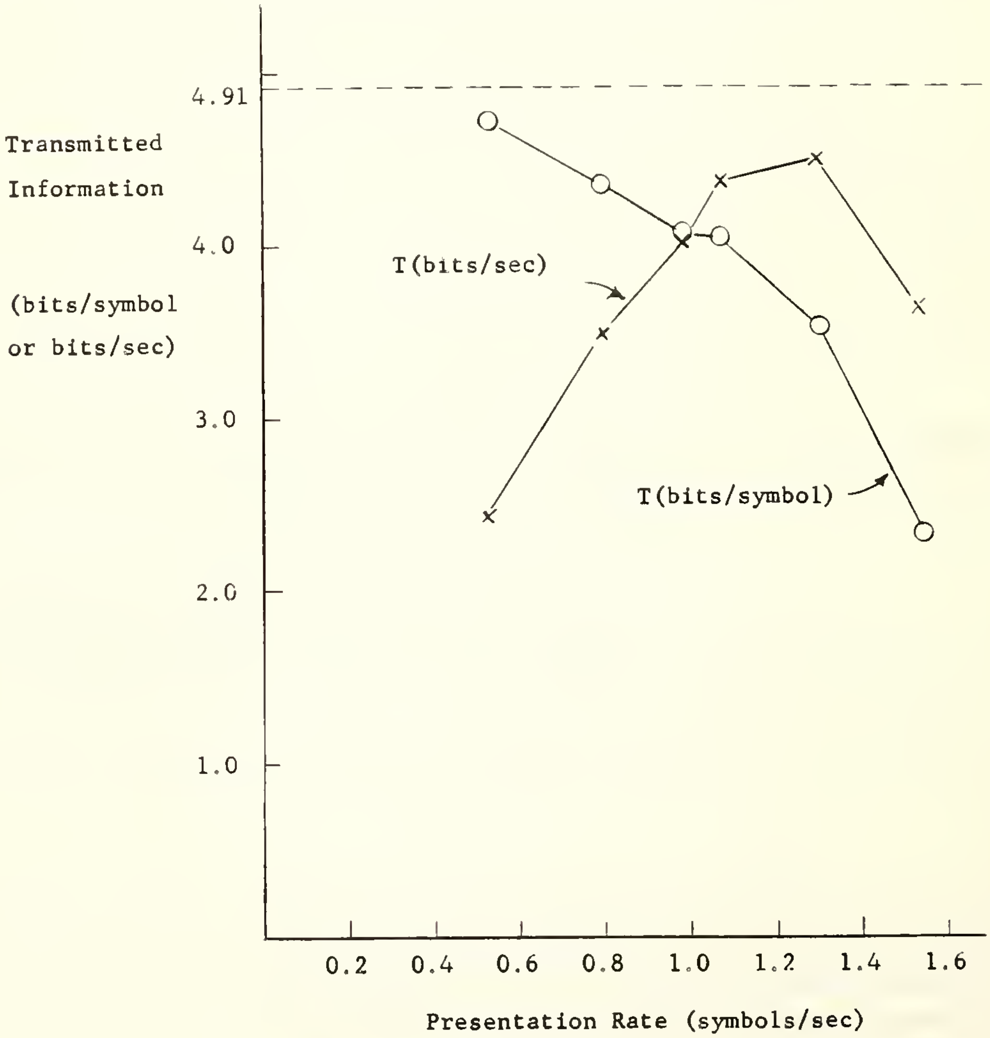

Fig. 4.4-3

INFORMATION RATES VERSUS PRESENTATION RATE
FOR THE TYPEWRITER DISPLAY

The maximum information rate obtained was 4.5 bits/sec, which occurred at a presentation rate of 1.32 letters/sec. However, this rate is probably not the maximum attainable for the following reasons:

1. More practice would probably increase the information rate. (The subject for this experiment had less than 15 hours of practice.)
2. The symbols in Typewriter Code are not optimally distributed among the fingers - six symbols are assigned to the index finger on each hand, while only three symbols are assigned to each of the other fingers. Consequently, 73% of the errors involved the 12 letters assigned to the index fingers.
3. The information rate could probably be increased if more than 30 alternatives were used.
4. The information rate could probably be increased if the subject were allowed to control the speed continuously.
5. Typewriter Code has the disadvantage of presenting each symbol only once, and not allowing the subject to "see" ahead.

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SUMMARY AND CONCLUSIONS

Main Contributions. The main contributions of this study are:

1. The suggestion of general methods to obtain high information rates using the kinesthetic and tactile senses.
2. Investigation of the potentialities of using passive movement for transmitting information.
3. Conception and development of a practical communication system using the kinesthetic-tactile senses.
4. Demonstration of an information rate obtainable with this system and suggestions for improvement.

Major Results. Some of the important results of this study on communication via the kinesthetic and tactile senses are summarized here.

A general model for a sensory-aid communication system is introduced. This model contains a source, sensor, processor, display, sensory channels, and user. The communication problem is to transmit information from the source to the user, subject to his fidelity criteria. Since experiments on human information transmission indicate that sequential restraints do not greatly affect the information rate, it may not always be desirable to remove this source redundancy. A coding rule is presented for the special case of a binary source with only monogram statistical constraints between messages. This rule is: transmit the most probable message most accurately.

The importance of an active role on the part of the user, so that there is re-afferent stimulation, is emphasized. Two methods for obtaining re-afferent stimulation are suggested. In one method, the user actively scans the display; and in the other method, the user exerts control over either the sensor, processor, display, or any combination of these.

Two hypothetical methods of obtaining high information rates are proposed. One method is analogous to such language forms as speech morphemes, Grade II braille, and stenotypy. In this method, the system recodes the source messages into approximately equal information units. The second method is analogous to visual reading, and the user recodes the messages into equal information units.

Four experiments that investigate the possibility of using passive movement to transmit information are described. In the first experiment, position-pulses of various widths and heights were applied to the subject's index finger. It was found that a difference in pulse height of less than 0.002 inch out of 0.025 inch, for pulses of 100 msec duration and 15 msec rise time, could be detected.

In the second set of experiments, position-pulses of various directions were applied to the subject's index finger. It was found that movements in the $\pm x$, $\pm y$, and $\pm z$ directions of about 3/16 inch can easily be discriminated. For the presentation of a sequence of three movements at a rate of 2.8 movements/sec, an information intake rate of 4.7 bits/sec was obtained.

The ability of subjects to localize pairs of fingers which are moved simultaneously in an up-direction was investigated in the third experiment. Most errors resulted from confusion between adjacent fingers on the same hand.

A comparison was made between the visual and the kinesthetic-tactile senses in a task of recognizing 1 x 6 matrix patterns. The error rate for the kinesthetic-tactile experiment was 10.5% compared with 0.25% for the visual experiment. Patterns in which the stimulated fingers were adjacent, for example 111000, resulted in a much lower error rate than patterns in which alternate fingers were stimulated, for example 010101.

A communication system is described in which the source is English text, the sensor is a typist, the processor is the TX-0 computer, and the display is an air-driven finger stimulator. The display device consists of eight finger rests, each of which can move in 26 directions in three-dimensional space. This device is programmed with perforated paper tape which serves as the slide in a pneumatic valve.

One presentation, the typewriter, was investigated in detail. An information transmission rate of 4.5 bits/sec for a continuous sequence of random letters was obtained with the typewriter display. However, it may be possible to exceed this rate with more learning and a better code.

Suggested Topics for Future Study.

1. The next phase of study could be the development of a reading machine with the typewriter presentation as an output. The typewriter presentation has the advantage of being easy to learn, especially if the subject has a previous knowledge of typing.

2. It was suggested that other presentations might result in a higher information rate than that obtainable with the typewriter presentation. The study described in this thesis explored some of the possibilities of using primarily passive movement to convey information. An investigation to compare various displays, after a prolonged learning period, would be necessary for a complete evaluation.

3. Communication systems in which the user recodes the source information into approximately equal information blocks may ultimately yield higher information rates. Realization of this method would be to use movements of two fingers in the $\pm x$, $\pm y$, and $\pm z$ directions to specify 36 symbols. Thus, four symbols could be presented to eight fingers at one time. This part of the display would be analogous to a rudimentary retina. To simulate the function performed by saccadic eye movements, a control which allows the subject

to shift the sequence of symbols to the right or left by any desired amount would be required.

4. One possibility for increasing the information rate is to increase the number of dimensions. The interaction of sensations produced by various forms of stimulation, such as passive movement, vibration, electrical shock, and contact, should be determined so that a stimulator which employs various orthogonal stimuli at the same location can be developed.

5. The air-driven finger stimulator described may have some potentialities for application in a teaching machine for typing.

6. The possibility of using passive movement to transmit pictorial information is interesting for application as a mobility aid for the blind.

7. Techniques for coding an arbitrary number of messages with sequential constraints into a set of stimuli could be developed. Various criteria could be maximized, such as information rate, probability of an error, minimum cost or risk, etc.

CORRELATES OF THE TACTUAL AND KINESTHETIC STIMULI IN THE BLIND MAN'S CANE

by

Leonard Potash

EDITOR'S NOTE:

This paper is based on a Master's thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the Department of Mechanical Engineering at the Massachussetts Institute of Technology in May 1961. The research was supported in part by the Department of Health, Education and Welfare (Office of Vocational Rehabilitation) under contract SAV-1004-61 and sponsored by the Division of Sponsored Research of M.I.T.

ABSTRACT

The cane is the device used almost universally by the blind for mobility and orientation. The precise reason has never been investigated. Therefore, this experiment has been designed to study the mechanical interactions between a blind man and his environment through the medium of the cane.

Preliminary experimentation indicated that force and displacement were the two principal correlates to be studied. Consequently, force discrimination thresholds were measured by the psychophysical method of jnd's (just noticeable differences) and the displacement discrimination level of a blind man with a cane was established by the "Fractionation" method.

The tests definitely indicated that force discrimination with the cane is not a significant function of the cane stiffness over a wide compliance range.

The numerical results of the experiment may be used for comparison with subsequent studies; and for the present may be used as two of the performance parameters of the cane-man system.

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INTRODUCTION

Perhaps one of the greatest problems confronting the blind is the ability to move about in a sighted world without the aid of a sighted guide. The two aspects of this problem are:

1. Mobility, or piloting, i.e., the avoidance of objects;
2. Orientation, or navigation, i.e., the control of one's motions by the recognition of objects. (K.S. Lashley in Zahl, 2).

In general the auditory sense becomes the blind man's principal modality for mobility and orientation. The so-called "obstacle sense" of the blind man has been independently shown to be a function of normal, but acutely trained, audition (6,7,8). However, in a significant number of circumstances, one's hearing must be reenforced by the somesthetic senses since extraneous noises can mask auditory cues. In addition, there are a great many obstacles to mobility which offer no auditory cues. It is to the detection of these obstacles that a great deal of research has been devoted during the past twelve years (9). In spite of several electronic obstacle detectors (10,11) which have been developed during this time the cane still remains the single artificial inanimate device used almost universally by the blind for mobility and orientation. Precisely why the cane is most satisfactory has never been established and a survey of the literature reveals no specific study toward this end. Therefore, on the hypothesis that there are mechanical interactions between a blind man and his environment through the medium of the cane, this study has been initiated to determine the nature and magnitude of these interactions.

Literature Review. It is essential that the researcher in sensory aids for the blind gain a comprehensive knowledge of blind sociology and psychology before any attempt can be made to scrutinize one isolated facet. Lende's bibliography provides general references about blind problems (5).

For foot travel aids, several sources (9,10,12,13) discuss specific requirements for mobility and orientation, while others (1,2,13) mention requirements for a cane in particular.

Arnold Auch (12) gives the following requirements for foot travel by the blind:

1. Following an obstruction line (a wall, fence, or shrub).
2. Walking in a straight line.
3. Detection of obstacles from the ground up, and also suspended obstructions such as tree branches.
4. Finding objects of curiosity and check points.
5. Detection of drop-offs and step-downs.
6. Travelling in snow; snow is "blind man's fog" due to absorption of virtually all sound.

The exact mechanism by which a cane or any other device can satisfy all, or even the major part of these requirements, is not explained in any of the references. However Levy (1), in 1872, mentions "this (stick) should be light and not elastic, in order that correct impressions may be transmitted from the objects with which it comes in contact to the hand of the user", "the stick is not only to discover the nature of the ground but also to defend the walker from objects at rest."

Immediately after World War II, R.E. Hoover (2) studied the mobility problem of blind veterans and devised a standard technique for the use of the cane. He theorized that the cane is primarily a bumper, and secondarily a probe. Consequently he developed, as part of the technique, the "long cane." This cane or a modification of it is used, along with the Hoover technique, in almost every blind rehabilitation center. The cane is described

in detail in the section on test apparatus, but briefly it is an aluminum tube, $\frac{1}{2}$ in. diameter, about 4 ft. long and tipped with a steel ferrule; the handle is a 4 in. crook. The Hoover technique for foot travel consists of sweeping the cane in rhythm with the gait and tapping the tip of the cane to the ground at the extremity of each arc so that any surface irregularities will be detected at the borders of the path width sufficiently wide to pass the traveller. The sweep of the cane provides continuous bumper duty for detection of ground obstacles while the tap of the cane one step ahead of the leading foot gives a sampled-data probe for step-downs. The salient feature of this technique is that the cane's most important function is the detection of step-downs and drop-offs. These indeed appear to be the greatest of stationary hazards to the blind. In fact several blind travelers (13,14) have advocated that the cane tip not be tapped at every step but, instead, be allowed to glide continuously over the terrain, particularly over unfamiliar ground, so that step-down information is continuous. Similarly, "shorelining," i.e., following an obstruction line such as a curb or lawn edge, must also be done on continuous contact basis unless roughness of the surface precludes this.

This brief review of foot travel, in general, and cane attributes and techniques, in particular, represents the significant thoughts and works done by workers for the blind in defining the task of the cane in mobility and orientation. Clearly, the cane must allow the blind man to study the geometry of his environment as well as to detect objects whose location, if hazardous, must be known.

Working in a somewhat similar area - determination of factors influencing proprioceptive feedback in aircraft control stick movements - experimental psychologists provide some references for the determination of the mechanics involved in accomplishing the task of the cane. These references will be discussed in connection with the design of this experiment.

DESIGN OF THE EXPERIMENT

Preliminary Experiment. In the beginning, these questions presented themselves:

1. How does one break the man-machine loop comprising the blind man and his environment in order to study interactions along one path - the cane?
2. What variables does the sightless man receive, consciously or unconsciously, while probing his environment for recognition of its pattern?
3. What are the magnitudes of these variables?
4. If the answer to question 2 can be assumed for a first approximation, how can the minimum useable magnitudes of the variables be determined?
5. Can the answers to questions 3 and 4 be used to arrive at a mechanical impedance match between the environment and the man, using the cane as the matching device; or from the engineering viewpoint, can the design of a cane be optimized for convenience (Hoover in (2)) without serious mechanical impedance mismatch?

Breaking the loop in question 1 is basically a neurological problem since the loop elements are not in cascade; e.g. a man cannot detect cutaneous pressure in his palm until he exerts a compression on the cane, therefore his response is a function of his exertion. However, it is possible to assume the interactions - the variables of question 2 - and selectively filter them while the blind-man machine system is in operation. This was accomplished by first assuming that the mechanical interactions between the blind man and his environment, for purposes of mobility and orientation, are: force, displacement, vibration and sound. Then a course, a long hallway containing normal obstacles, was traversed for a performance rating. The performance criterion was the inverse of time required to traverse the course. Several traverses were made during each of which the subject's aural channel was jammed by the use of white noise in a set of soundproof earphones

which he wore. During the first traverse, a normal long cane was used and the subject showed no significant variations from his normal mode other than a slight meandering of course due to deprivation of his audio cues (15). For the next traverse, a force-free cane, Fig. 1, was used. This cane was a conventional long cane in which the shaft had been cut and a universal joint inserted at the cut. The resulting removal of virtually all force transmission from the cane input at the tip, to the output at the handle, rendered the subject completely disoriented since his geometry input appeared to have vanished with the force removal. The last traverse was made with a vibration damped cane in which a normal long cane shaft had been cut and a soft rubber hose inserted to separate the two pieces of tubing. The results of this traverse were extremely interesting. The sweep of the cane was naturally somewhat erratic since the greatly reduced stiffness caused the cane lateral motion to become uncoupled from the subject's sweeping motion, the normal sweep rate of which far exceeded the extremely low natural frequency of this modified cane. None-the-less the subject was able to traverse the course in almost the same time as with the normal cane. Furthermore, when the gliding tip technique (14) was employed rather than the tapping method of Hoover, step-downs were detected as readily as with the normal cane whose stiffness exceeded that of the vibration-free cane by more than an order of magnitude. This can best be explained by observing that the vibration-free canedid not completely block vibration but simply greatly attenuated the vibration displacement; however since the vibration displacement sensitivity is high (4,16) at the palm of the hand - motions of 10 microns may be detected - there was sufficient amplitude of vibration coming through the dampener to excite a response in the subject. As soon as the gliding tip slid over the step-down ledge, the subject stopped in the same manner as if he was using the normal long cane. Further increase of the low frequency damping of the cane did not increase the traverse time.

As a result of these modified cane traverses, the following conclusion was inferred: those mechanical interactions between a blind man and his environment, which most grossly affect his mobility and orientation performance with the cane, i.e., his geometric discrimination, are time-variant forces such as vibrations and impulses, and spatial-dependent forces such as the forces complementing displacement and angle changes which the blind detect while "shore-lining."

Admittedly the above conclusion is partly a prediction based on an assumption and demonstrated qualitatively by a non-rigorous method. However, it serves well as a first approximation in the solution of this untried problem. A group of workers, under Professor T.B. Sheridan, is at present attempting to answer questions 2 and 3 using strain-gage instrumented canes. Their results will appear in a later publication.

The results of the traverse experiments were used to answer question 4 which served as a vehicle for the final design of this experiment, i.e., a quantitative study of the correlates - force and displacement - of the tactile-kinesthetic stimuli. A study of the force and time dimensions of the tactile-kinesthetic stimuli could be done to establish the minimum vibration levels necessary to produce a response in the blind man; but several studies (4,17,18) indicate, in agreement with the forementioned vibration-free traverse, that a human is sufficiently sensitive to the vibration stimulus that there is virtually no subliminal level greater than zero that can be measured.

Final Experimental Design. The final design of this experiment, then, was to provide a study of the forces and displacements which a sightless person can detect through the use of a cane. The philosophy of the design was to maximize simplicity and reliability of method and apparatus.

Nothing more sophisticated than the conventional psychophysical methods of differential threshold determinations were used in the study of the ability of the blind to

DEPTH
FRACTIONATION

FIG. 2

FORCE - FREE
CANE
TRAVERSE

FIG. 1

discriminate forces. See Table 1. Basically, the test was a measure of the force resolution of the man using the cane. There was little precedence to follow in using this method of jnd's (just noticeable differences) though one experimenter in aircraft control man-machine systems did use this method (22).

The test apparatus, which will be described in the next section, provided a convenient, accurate, and reliable method of rapidly offering the subject a reference force r and then a comparison force C where

$$C = R + \Delta R \quad \text{and} \quad 2\% < \frac{\Delta R}{R} < 32\%$$

The reference force R was obtained by the combination of a CONSTANT and a REFERENCE where the CONSTANT was a spring constant K and the REFERENCE was a deflection δ or else the CONSTANT was a deflection δ and the REFERENCE was a spring constant K.

The comparison force C was obtained by changing the REFERENCE by a small $\pm$ increment ΔR from its reference force position while the CONSTANT remained at its same setting.

In the $\frac{\Delta\delta}{\delta}$ Variable Treatments, see Table 1, the ΔR was derived from maintaining the spring constant K of variable K spring at a CONSTANT level and varying the REFERENCE deflection δ by an amount $\Delta\delta$ such that

$$C = K\ (\delta + \Delta\delta).$$

After a series of twenty random comparisons at a given R ($\Delta\delta$ in the $\frac{\Delta\delta}{\delta}$ Variable Treatments) in which the subject was forced to decide whether the C was a higher or lower force than R, the ΔR was changed and the series of twenty comparisons were repeated. Generally five ΔR were used for every level of CONSTANT, and there were four levels of CONSTANT (K in $\frac{\Delta\delta}{\delta}$ Variable Treatments) for every Variable Treatment $\frac{\Delta\delta}{\delta}$.

In the $\frac{\Delta K}{K}$ Variable Treatments, see Table 1, the ΔR was derived from maintaining the δ (deflection micrometer setting) at a CONSTANT level and varying the REFERENCE K by an amount ΔK such that

$$C = \delta(K + \Delta K).$$

Again the subject was given a series of twenty random comparisons at a given ΔR(ΔK in the $\frac{\Delta K}{K}$ Variable Treatment) in which he was forced to decide whether the C was a higher or lower force than R. Then the ΔR was changed and the series of twenty comparisons were repeated. Generally five ΔR were used for every level of CONSTANT, and there were four levels of CONSTANT (δ in $\frac{\Delta K}{K}$ Variable Treatments) for every Variable Treatment $\frac{\Delta K}{K}$.

A third set of Variable Treatments $\frac{\Delta K}{K}$ was added to the force discrimination test, in which there was no constant δ ; the subject pushed as hard as he wanted. This set was a control to test whether the results of the $\frac{\Delta K}{K}$ Variable Treatment with CONSTANT δ were due to the variation in force or the variation in K.

The entire test was conducted at three different force levels:

1. 10 lb. compression
2. 1 lb. compression
3. 0.1 lb. lateral.

In the compression tests, the cane was grasped as in Fig. 3 and the cane was pushed into the variable spring socket until the socket came down against the deflection micrometer stop. At that point the subject felt the R or C stimulus. The time span between feeling R and feeling C was $0.5 < T < 1$ seconds. Not only were the two compression force tests separated by an order of magnitude in force level, but the CONSTANTS generally spanned an order of magnitude. See Table 1.

In the lateral force test, the force level was calculated to be 0.1 lb. assuming an average coefficient of friction of 0.4 and a pavement reaction force on the cane ferrule of 0.25 lb. This force level was subjectively verified by Mr. John Dupress, Director of Technilogical Research, American Foundation for the Blind. The compression test force levels of 10 lb. and 1 lb. were estimated on the basis of the traverse observations.

Fig. 4 illustrates the stance and grasp used in the lateral force test. It is of interest to note that subjtcts' wrists tired after about 15 minutes of lateral tests at which time the lateral degree of freedom grasp, as in Fig. 1, was used for lateral cane motion. A series of tests revealed no significant difference between the two grasps with respect to force differentiation. Naturally, in the lateral tests the subjects exerted no compression pressure on the cane handle, just a lateral sweeping type motion.

Four subjects were used in the compression tests while three were used in the lateral tests. All subjects were M.I.T. students, age 19 to 23, of normal appearance and physique. Two of the subjects were left-handed. Blindfolds were used in all tests. Prior to each series of twenty comparisons the subject was allowed sufficient cane presses against the spring to eliminate any learning curve bias. The design of the test was a Treatment X Subject experiment wherein every subject underwent every treatment. Some fatigue undoubtedly appeared but the order of CONSTANTS was randomized to neutralize the fatigue effect.

It was extremely difficult to make any hypotheses in the beginning since no work had been done in this area previously, and the conclusions of the aircraft control experimenters (20,21,22,23) are inconsistent to the point of direct opposition, in some cases, with reference to force and displacement proprioceptive feedback from spring-loaded stick forces.

<u>Displacement Discrimination Test.</u> The displacement tests were designed for simplicity and reliability. The fractionation method of psychophysics was used since "halving is a wonderfully simple psychological operation" (3) which is used continually by the blind in aligning themselves for street crossing, stair traverses, and moving in narrow passages.

In this test the subjects performed two orthogonal fractionations. The first consisted of a blindfolded subject sweeping his cane across the floor in front of him from an approximate straight ahead position, in an arc first to a stop on his left front, then 24 in. to a stop on his right front and then splitting the 24 in. sweep by stopping his cane at a point he felt was half way in-between the right and left stop. Errors were tabulated in the conventional positioning-error psychophysical method. Twelve subjects were used, half of whom shifted their position after each of the forty determinations made for the lateral axis. The orthogonal fractionation, see Fig. 2, consisted of repeating the above test, i.e. splitting a 24 in. sweep, except that the depth axis (forward from the subject) was used. The subject moved his cane along the floor between two stops on his fore-and-aft path directly in front of him. The distance again was 24 in. and again half of the twelve subjects shifted position after each of forty determinations. The constant error - mean distance from center, and the variable error - standard deviation of the distances from center - were computed for both axes.

In the fractionation tests, the floor was covered with paper for homogeneity of surface. Subjects reported no cues other than the stops themselves.

Table 1

Experimental Design

Force Discrimination Tests

10 lb. Compression

Variable Treatment		$\frac{\Delta \delta}{\delta}$				$\frac{\Delta K}{K}$				Control Treatment $\frac{\Delta K}{K}$ NoStop			
REFERENCE R		1.0 in	0.5 in	0.2 in	0.1 in	10 lb/in	20 lb/in	50 lb/in	100 lb/in	10 lb/in	20 lb/in	50 lb/in	100 lb/in
CONSTANT		10	20	50	100	1.0 in	0.5 in	0.2 in	0.1 in	———			
Subject	ΔR %	———				———				———			
1	2												
	4												
	8												
	16												
	32												
2	2												
	4												
	8												
	16												
	32												
3	2												
	4												
	8												
	16												
	32												
4	2												
	4												
	8												
	16												
	32												

Note: Each block contains % correct of 20 discriminations

Table 1

Experimental Design

Force Discrimination Tests

0.1 lb. Lateral

Variable Treatment		$\frac{\Delta\delta}{\delta}$			$\frac{\Delta K}{K}$			$\frac{\Delta K}{K}$ No Stop		
REFERENCE R		0.4 in	0.2 in	0.1 in	0.25 lb/in	0.5 lb/in	1.0 lb/in	0.25 lb/in	0.50 lb/in	1.0 lb/in
CONSTANT		0.25 lb/in	0.5 lb/in	1.0 lb/in	0.4 in	0.2 in	0.1 in	—		
Subject	ΔR %	—			—			—		
1	2									
	4									
	8									
	16									
	32									
2	2									
	4									
	8									
	16									
	32									
3	2									
	4									
	8									
	16									
	32									

Note: Each block contains % correct of 20 discriminations.

Table 1

Experimental Design

Force Discrimination Tests

1.0 lb. Compression

Variable Treatment		$\frac{\Delta\delta}{\delta}$				$\frac{\Delta K}{K}$				$\frac{\Delta K}{K}$ No Stop			
REFERENCE R		0.8 in	0.4 in	0.2 in	0.1 in	1.25 lb/in	2.5 lb/in	5 lb/in	10 lb/in	1.25 lb/in	2.5 lb/in	5 lb/in	10 lb/in
CONSTANT		1.25	2.5	5	10	0.8 in	0.4 in	0.2 in	0.1 in				
Subject	ΔR %												
1	2												
	4												
	8												
	16												
	32												
2	2												
	4												
	8												
	16												
	32												
3	2												
	4												
	8												
	16												
	32												
4	2												
	4												
	8												
	16												
	32												

Note: Each block contains % correct of 20 discriminations.

LATERAL
FORCE
DISCRIMINATION

FIG. 4

COMPRESSION
FORCE
DISCRIMINATION

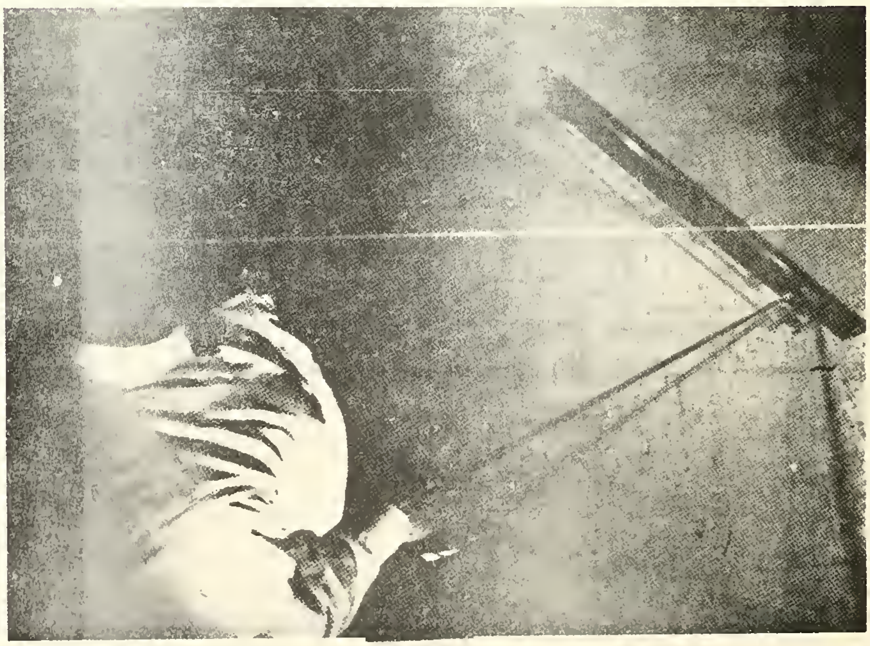


FIG. 3

TEST APPARATUS

Subjects. All subjects were male, M.I.T. students, ages 19 to 23. None were in any way unusual and their performance curves were in no way indicative of subject trend. Indeed the sample was as homogeneous as an experimenter could expect. None of the subjects in the force and displacement tests were blind since it was felt that the use of blind subjects for 20 one-hour sessions apiece could provide non-technical difficulties that exceeded the experimental problems. Furthermore, there appeared to be no particular advantage in using blind subjects where differences of background and length of blindness might grossly bias the results.

The displacement test subjects were not paid, the others were hourly paid. Subjects, in general, were quick to report experimental technique anomalies and were very helpful in suggesting solutions - some of which were used.

Test Specimen. The long canes used were manufactured by the Mah-zell Co. of Brooklyn, N.Y. Test specimens weighed $\frac{1}{2}$ lb., were 55 in. long, 0.5 in. O.D., duraluminum tubing, 0.050 in. thick, and had a replaceable steel ferrule with rubber washer sound dampener.

The longitudinal spring constant of this cane is 225 lb./in. while the lateral spring constant is 0.5 lb/in. assuming that the cane is rigidly grasped at the handle, and the input force is applied at the ferrule.

These canes are identical to those used in two blind training centers in the Boston area. The canes are available to the blind at a cost of about $2.

Variable K Spring and Deflection Micrometer. The variable K spring, Fig.5, is an ordinary cantilever construction with a sliding block knife-edge which serves to vary the spring constant as a function of the block distance from the tip of the leaf. There are three leaves, one for each force test, and leaves vary from $\frac{1}{4}$ in. thick ($10 < K < 360$ lb/in.) to 1/16 in. thick ($0.12 < K < 4$ lb/in.). Each leaf can mount either a compression socket, as in Fig. 5, or a lateral socket, as in Fig. 4.

The deflection micrometer is a closely fitted 3/4" x 10 N.C. steel lead screw and disc. The disc is graduated to 0.005 in. and is easily adjustable to 0.001 in.

Calibration of the three leaves was done by precise deadweight loading and micrometer measurement of δ for each $\frac{1}{2}$ in. of movement of the sliding block knife-edge. The calibration curves were fairly smooth cubics.

For the compression mode, the spring base - a 2in. angle iron - was floor mounted and gave the cane a 45° address. For the lateral mode, the spring lay at a 10° angle to the floor in order to use the very slight gravity component for preloading the spring by enough force to keep it in contact with the sliding block.

EXPERIMENTAL RESULTS

Force Test Discussion. The force discrimination test data is quite lengthly since it represents over 12,000 discrete force discriminations. The results are tabulated in Table 2, and are plotted on the three Weber Fraction Graphs, Figs. 6, 7, and 8.

Each Weber Fraction Graph contains the differential limen of all subjects for each variable treatment, $\frac{\Delta R}{R}$. The abscissa Variable is plotted as K with its respective comp-

lement δ beneath it. The abscissa R could have been plotted as δ with its complement K beneath it. In any case the product of the Variable with its complement must always equal the reference force level R of the test. Note, however, that the Weber Fraction Graphs do not plot $\frac{\Delta R}{R}$ versus R since the force R of each graph is a constant.

A Weber Fraction curve could be constructed from the three force test averages to show $\frac{\Delta R}{R}$ versus R by taking the mean differential limen of all jnd's in the constant K and constant δ treatments of each R force level. This would require making an assumption that the lateral force discrimination treatments were from the same population as the compression force tests. There is no evidence or basis for such an assumption. There is good basis, however, for averaging the constant δ and constant K treatments together since statistical significance tests indicate no significant population difference between the force discriminations made in the variable δ (constant K) treatments and the variable K (constant δ) treatments for a given force level. This does not include the data from the control test (variable K, no stop).

Clearly, it appears that when the cane is used to make compression force discriminations, the blind man is capable of detecting force differences of 5.4% at the 10 lb. force level and 5.8% at the 1 lb. level. In addition, it doesn't matter whether the increment of force is derived from an increase in K or an increase in δ over a range of $1 < K < 100$ lb./in and $0.1 < \delta < 1.0$ in. A cautious reminder is that the canes used to obtain these conclusions had a longitudinal spring constant of 225 lb./in. and a lateral spring constant of 0.5 lb./in. For lateral forces of 0.1 lb. the data indicates a mean differential limen of 8.3%.

One experimenter (22) obtained remarkable agreement when measuring differential limen in positioning a spring loaded control stick. He indicated 6% differential limen between forces of 1 lb. and 10 lb. with higher thresholds at force levels below 1 lb. One possible explanation for the rise in thresholds as the lower force levels are approached, is that the intensitive threshold of a man is being approached and, as has been shown countless times in all standard experimental psychology books, the Weber fraction is not a constant at low intensity ranges but rises sharply in the area of the lowest level of intensity that man can detect.

The control treatment is not, strictly speaking, part of the force discrimination test since the test spring could be depressed to any δ, and therefore any force, that the subject desired. This treatment was used, in addition to its control function in the design, to test a hypothesis that the cane user could readily discriminate changes in spring constant without any reference to a definite force level obtained by limiting the deflection to a definite δ. The data of the control treatment in the 1 lb. compression test would seem to bear this out, but the control treatment in the 10 lb. compression and 0.1 lb. lateral test indicate a definite reduction in K discrimination.

One immediately observes, see Table 2, that in the 1 lb. compression test, the spring constant of the cane far exceeds that of the test spring, by more than an order of magnitude while in the other two tests the spring constants are not so widely separated. Therefore, in effect, the cane is an infinitely stiff spring in this particular 1.0 lb. force man-cane-environment system, and the effective stiffness of the system approaches the stiffness of the test spring.

In the control treatment, when the cane is effectively an infinitely stiff spring, the discrimination process is simplified since for all practical purposes the cane does not deflect at all and the subject simply had to : make a subjective estimate of the deflection of his reference motion; try to duplicate this deflection in his comparison motion; then judge which of the two motions produced the heavier force. Of course, one may take the reciprocal approach, i.e., the subject estimates the reference force which

VARIABLE K SPRING AND DEFLECTION MICROMETER

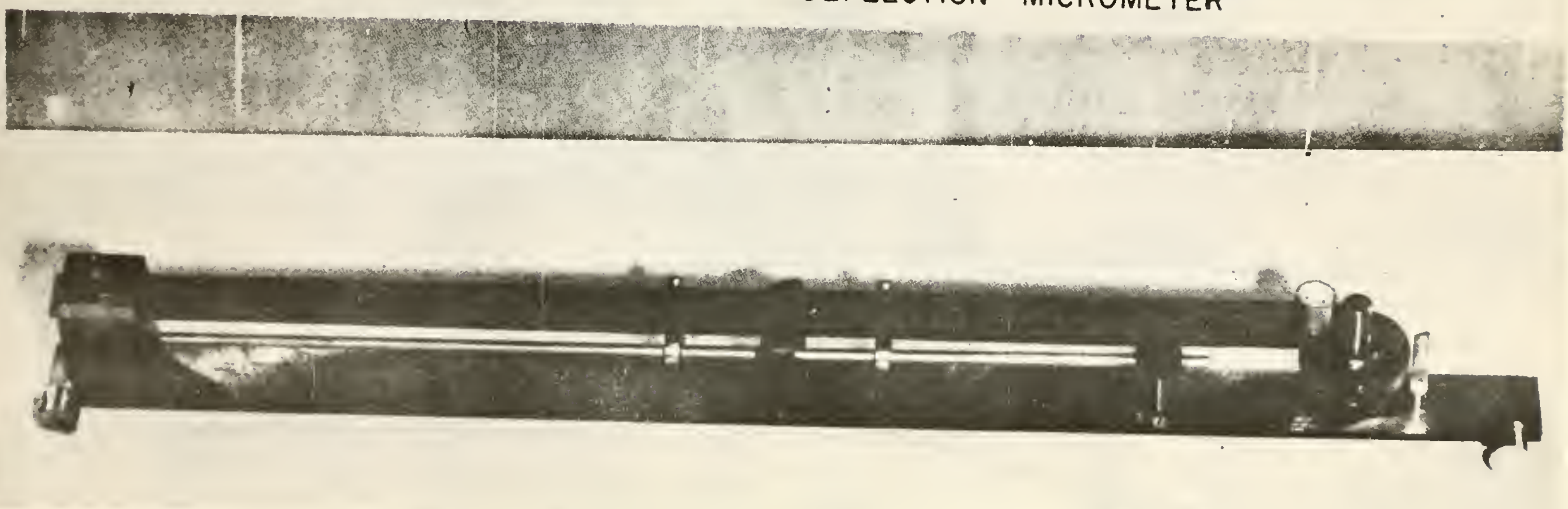


FIG. 5

WEBER FRACTIONS—0.1 LB. FORCE—LATERAL

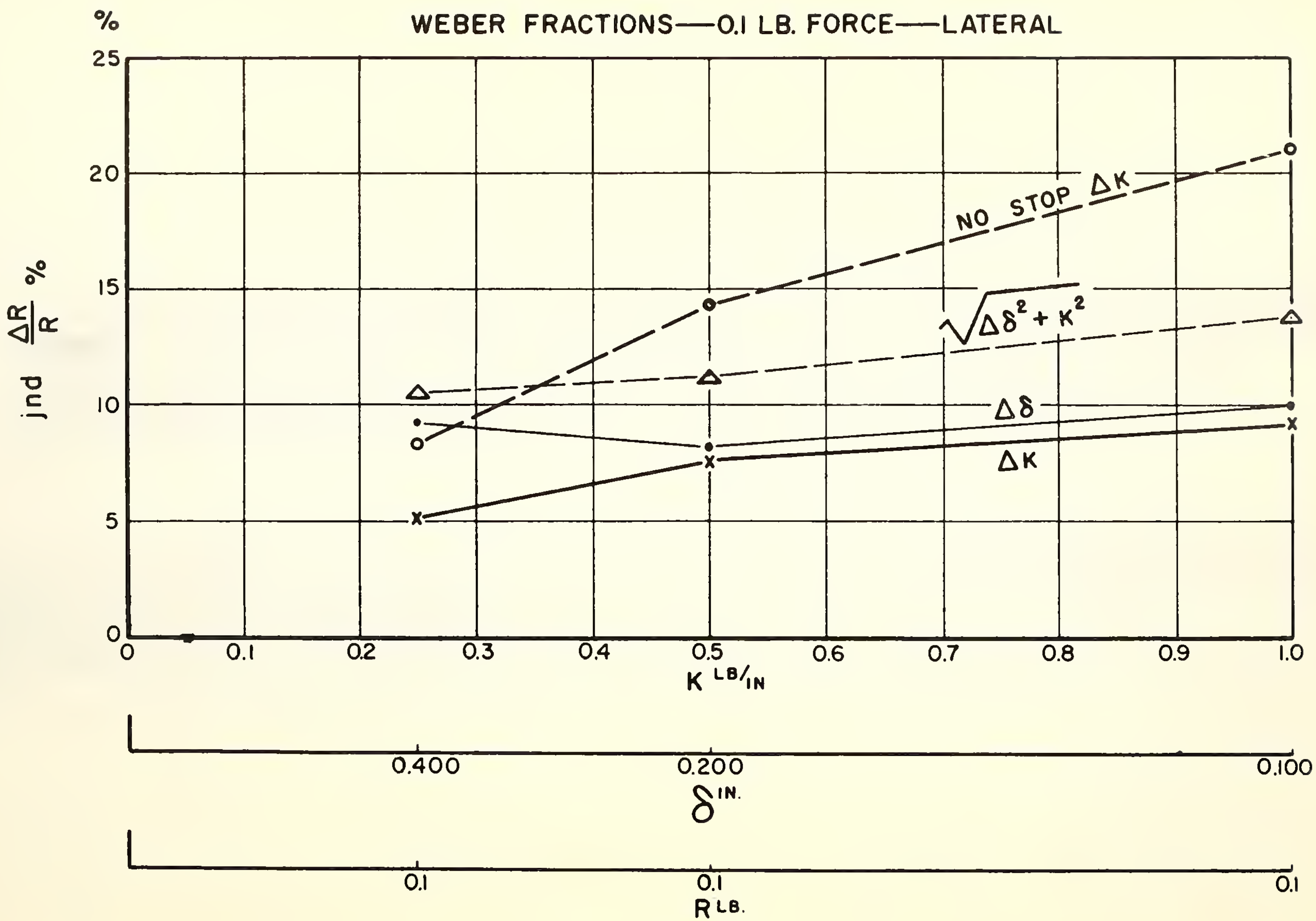
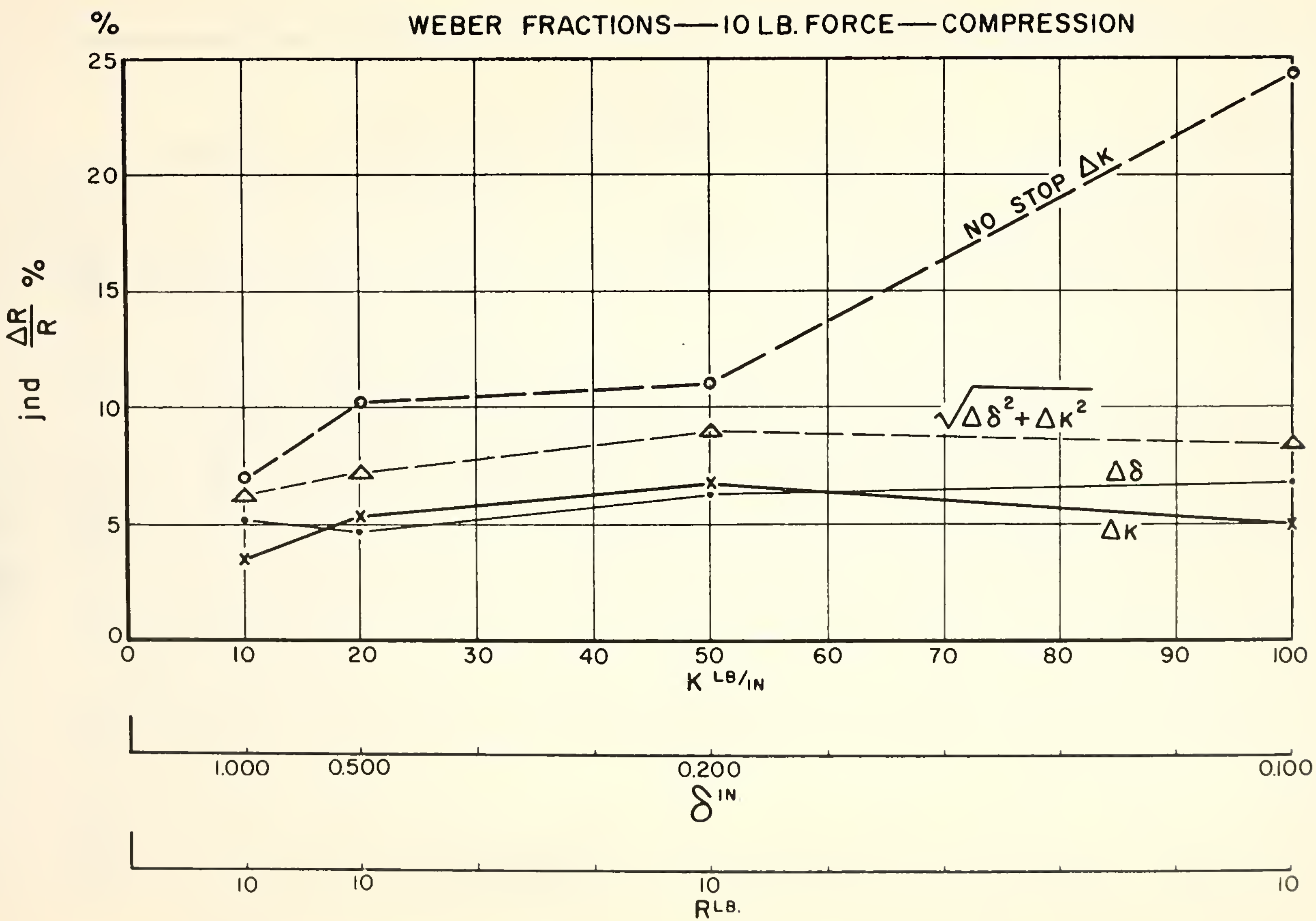
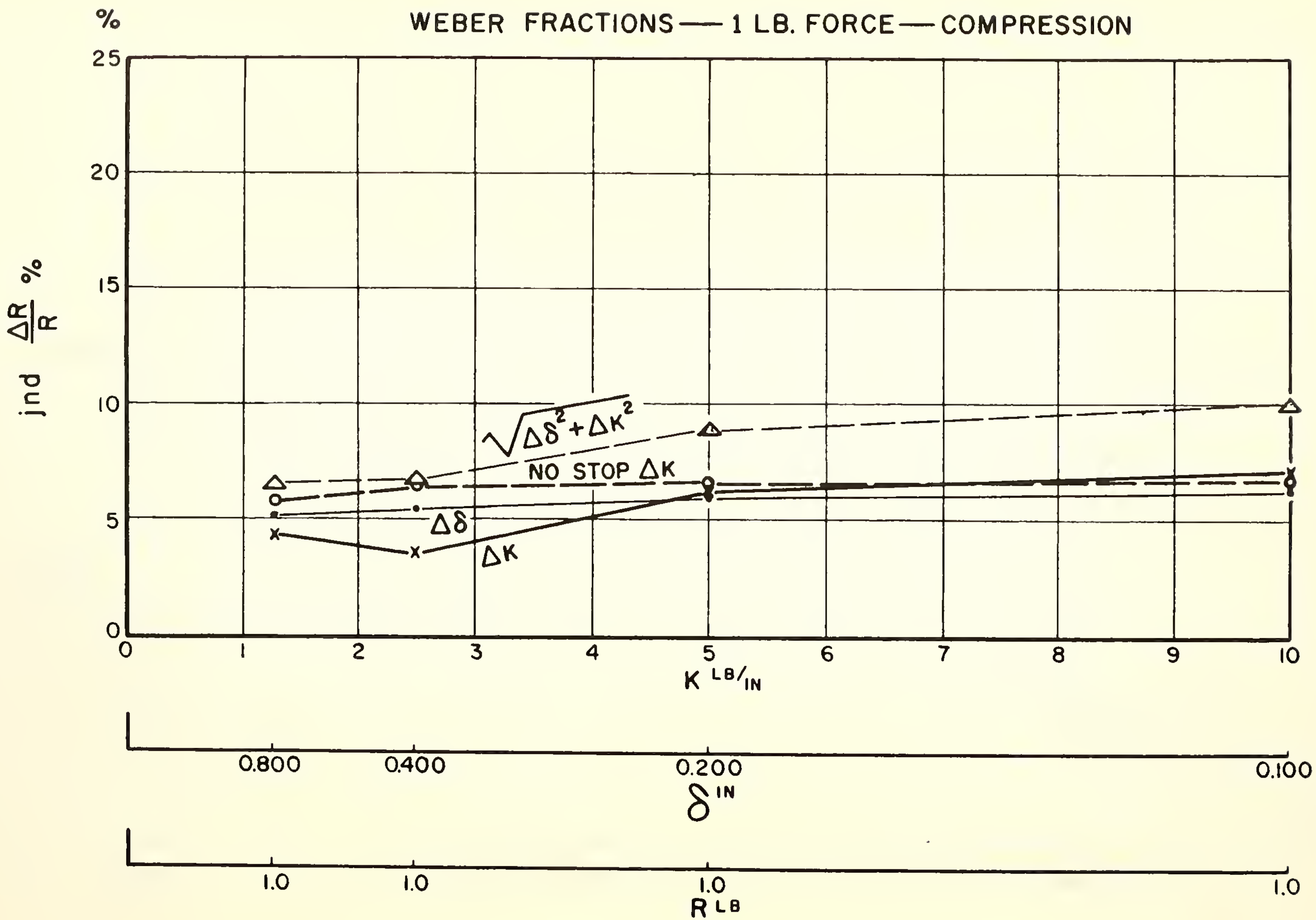


FIG. 8



WEBER FRACTIONS — 10 LB. FORCE — COMPRESSION
%
jnd $\frac{\Delta R}{R}$ %
NO STOP ΔK
$\sqrt{\Delta\delta^2 + \Delta K^2}$
$\Delta\delta$
ΔK
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
100
K LB/IN
1.000
0.500
0.200
0.100
δ^{IN}
10
10
10
10
$R^{LB.}$

FIG. 6



WEBER FRACTIONS — 1 LB. FORCE — COMPRESSION
%
25
20
15
10
5
0
jnd $\frac{\Delta R}{R}$ %
$\sqrt{\Delta\delta^2+\Delta K^2}$
NO STOP ΔK
$\Delta\delta$
ΔK
0
1
2
3
4
5
6
7
8
9
10
$K^{LB/IN}$
0.800
0.400
0.200
0.100
δ^{IN}
1.0
1.0
1.0
1.0
R^{LB}

FIG. 7

Table 2

Experimental Results

Force Discrimination 10 lb. Compression

Variable Treatment $\frac{\Delta \delta}{\delta}$			Variable Treatment $\frac{\Delta K}{K}$			Control Treatment $\frac{\Delta K}{K}$ NoStop		Possible Interaction of Variable Treatments
CONSTANT K lb/in	REFERENCE δ in.	$\overline{jnd}$ %	CONSTANT δ in.	REFERENCE K lb/in	$\overline{jnd}_K$ %	REFERENCE K lb/in	$\overline{jnd}$ %.	$\sqrt{\overline{jnd}^2 + \overline{jnd}_K^2}$ %
10.0	1.000	5.08	1.000	10.0	3.48	10.0	7.00	6.15
20.0	0.500	4.75	0.500	20.0	5.34	20.0	10.29	7.15
50.0	0.200	6.06	0.200	50.0	6.41	50.0	11.20	8.82
100.0	0.100	6.85	0.100	100.0	5.05	100.0	24.42	8.51
	$\overline{\overline{jnd}}$	5.69		$\overline{\overline{jnd}}$	5.07	$\overline{\overline{jnd}}$	13.20	
	SD	0.95		SD	1.21	SD	7.69	

$CR_{(\text{Variable Treatments})} = 0.81$

$CR_{(\frac{\Delta K}{K} \text{ Treatments})} = 2.10$

Explanation of Terms

$\overline{jnd}$ = jnd's averaged across subjects at each CONSTANT level

$\overline{\overline{jnd}}$ = Sample Mean jnd for each treatment = $\frac{\sum \overline{jnd}}{N}$, where N = number of $\overline{jnd}$'s = 4

SD = Sample Standard Deviation = $\frac{\sqrt{(\overline{jnd} - \overline{\overline{jnd}})^2}}{N - 1}$

σ_x = Standard error of the Sample Mean = $\frac{SD}{\sqrt{N}}$

CR = Critical Ratio of the difference in Sample Means = $\left[\frac{\overline{\overline{jnd}}_1 - \overline{\overline{jnd}}_2}{\sqrt{\sigma_{x_1}^2 + \sigma_{x_2}^2}}\right]$, and indicates a significant difference in Sample Means if CR > 1.96.

Table 2

Experimental Results

Force Discrimination 1 lb. Compression

Variable Treatment $\frac{\Delta\delta}{\delta}$			Variable Treatment $\frac{\Delta K}{K}$			Control Treatment $\frac{\Delta K}{K}$ NoStop		Possible Interaction of Variable Treatments
CONSTANT K lb/in	REFERENCE δ in.	$\overline{jnd}$ %	CONSTANT δ in.	REFERENCE K lb/in	$\overline{jnd}_K$ %	REFERENCE K lb/in	$\overline{jnd}_K$ %	$\sqrt{\overline{jnd}_\delta^2 + \overline{jnd}_K^2}$ %
1.25	0.800	5.31	0.800	1.25	4.53	1.25	5.87	6.98
2.50	0.400	5.80	0.400	2.50	3.47	2.50	6.55	6.75
5.00	0.200	6.28	0.200	5.00	6.48	5.00	6.79	9.02
10.00	0.100	6.82	0.100	10.00	7.60	10.00	6.76	10.21
	$\overline{\overline{jnd}}$	6.05		$\overline{\overline{jnd}}$	5.52	$\overline{\overline{jnd}}$	6.50	
	SD	0.65		SD	1.42	SD	0.43	

$CR_{(\text{Variable Treatments})} = 0.68$

$CR_{(\frac{\Delta K}{K}\ \text{Treatments})} = 1.32$

See page 28 for explanation of terms.

Table 2

Experimental Results

Force Discrimination 0.1 lb. Lateral

Variable Treatment $\frac{\Delta\delta}{\delta}$			Variable Treatment $\frac{\Delta K}{K}$			Control Treatment $\frac{\Delta K}{K}$ NoStop		Possible Interaction of Variable Treatments
CONSTANT K lb/in	REFERENCE δ in.	$\overline{\text{jnd}}$ %	CONSTANT δ in.	REFERENCE K lb/in	$\overline{\text{jnd}}_K$ %	REFERENCE K lb/in	$\overline{\text{jnd}}$ %	$\sqrt{\overline{\text{jnd}}_\delta^{\,2} + \overline{\text{jnd}}_K^{\,2}}$ %
0.25	0.400	9.09	0.400	0.25	5.16	0.25	8.37	10.42
0.50	0.200	8.17	0.200	0.50	7.89	0.50	14.17	11.34
1.00	0.100	10.09	0.100	1.00	9.41	1.00	21.13	13.80
	$\overline{\overline{\text{jnd}}}$	9.12		$\overline{\overline{\text{jnd}}}$	7.49	$\overline{\overline{\text{jnd}}}$	14.56	
	SD	0.96		SD	2.15	SD	6.38	

$CR_{(\text{Variable Treatments})} = 1.20$

$CR_{(\frac{\Delta K}{K}\ \text{Treatments})} = 1.82$

See page 28 for explanation of terms.

Note: N = 3 in the above test.

he has produced - it can be any value; pushes the cane down for the comparison motion until he feels that the comparison force equals the reference force; then judges which deflection was the greater. However this reciprocal approach does not appear to be valid, for in the $\frac{\Delta\delta}{\delta}$ Variable Treatment (fixed K, variable δ) the differential limen observed was not significantly lower than the differential limen observed in the $\frac{\Delta K}{K}$ Variable Treatment when the force was incremented by a change of K instead of δ. In fact the $\Delta\delta$ jnd's were slightly higher, though not significantly. The inference is that the force discrimination of a man-cane system is not a function of K or δ alone but a combination of these variables.

If the aircraft control stick experimenters previous work can be used as a comparison, it may be noted that one source (21) indicates δ as the variable affecting positioning responses by proprioceptive feedback while another experimenter (23) takes the view that variations in K are the primary parameter changes affecting the man-machine response. Other works (19,20) develop the relationship between force and displacement as variables affecting position error, in flight control sticks, by a ratio: positioning error $\sim \frac{F\delta}{\Delta F}$. Now if $K = \frac{\Delta F}{\Delta\delta}$ we can restate the ratio as position error $\sim \frac{F}{K}$. The results of the control treatment tests (variables K, No-stop) tend to show agreement with this relationship.

When the test spring stiffness approaches to within about 50% of the cane stiffness, the springs-in-series effect reduces the increment of the effective spring constant of the cane-test spring system. Hence the 1 lb. compression control tests showed much better K discrimination since the highest test spring K used in that test was 4% of the cane K.

Also, it was observed that during 10 lb. and 0.1 lb. control tests, the subjects almost invariably pushed on the cane with a greater force than the reference force of the two fixed force treatments; e.g. in the 10 lb. compression force tests, the subjects pushed on the cane with forces up to 100 lb. during the control treatments - $\frac{\Delta K}{K}$ No-stop, and the canes flexed a great deal. This high force coupled with the reduced effective increment, ΔK, of the cane-spring system gave a high $\frac{F}{K}$ ratio which might account for the poor discrimination of compliance changes when cane K approaches spring K.

Another basis for explanation as to why compliance discrimination differed so much from force discrimination for the same level of K might be the possible interaction of the differential limen of the variable δ treatment with that of the variable K, constant δ, treatment. The results are tabulated in Table 1. and are plotted with the Weber Fraction Graphs, Figs. 6, 7 and 8. The results are inconclusive.

Force Test Conclusions. The following may be said of the force correlate of the somesthetic stimuli through the blind man's convential long cane:

1. Force discrimination or resolution appears to be at about the $5\frac{1}{2}$% differential level for forces between 1 lb. and 10 lb. along the compression axis of the cane.
2. The differential threshold of force discrimination appears to be higher, about $8\frac{1}{2}$%, for a force of 0.1 lb. in the lateral axis.
3. The stiffness of the cane with respect to the environmental stiffness, does not significantly affect force discrimination. It does, however, affect compliance resolution when cane K approaches environmental K.

Displacement Test Discussion. Each of the four treatments was repeated 40 times by each subject and the statistics averaged across subjects. The two lateral treatments are significantly different at the 1% level while the depth treatments are not different.

	Lateral			Depth		
	CE in.	SD in.	CR	CE in.	SD in.	CR
Shift	-0.25 lt	1.34	2.89	-0.20 back	1.09	0.60
No-shift	+0.61 rt	1.19		-0.36 back	1.17	

CE = Constant Error; SD = Standard Deviation; CR = Critical Ratio

The variability as indicated by the standard deviations shows remarkable uniformity considering the change from a shifting stance to no-shifting between determinations. The variability is the parameter of greatest interest, and it indicates a measure of displacement resolution obtainable with the long cane. This resolution or differential threshold of distance discrimination is about 10% if the SD is divided by one-half of the total sweep, 24 in. Goldscheider (4) measured a discrimination of motion at the shoulder joint of about 20' of arc. This is considerably better than the variability obtained in this test using the long cane. The 1.2 in. average standard deviation at the maximum distance of six feet from shoulder to canetip is about 1° of arc. Since there is only one other experiment to compare these results with, and that experiment did not use a cane, the best assumption is that the 10 % distance threshold is a reasonable parameter in the man-cane distance discrimination system.

It might be noted that the 0.1 lb. lateral force average differential limen was 9.12% while the average lateral distance standard deviation was 10.5%. The similarity of threshold levels may be significant but it is difficult to show the correlation from this experiment.

Displacement Test Conclusions. The conclusion of interest in this test is:

1. The distance discrimination threshold for the blind using the long cane appears to be 10% for both lateral and depth fractionations. This threshold might be improved with practice.

Future Investigations. Since this is an initial attempt to study the mechanical interactions between a blind man and his environment through the medium of the cane, there are many areas of the problem yet to be explored.

Future investigations specifically connected with this study are numerous. A few are enumerated:

1. Determine whether higher threshold in the 0.1 lb. lateral force test was due to lower sensitivity of muscles used in the lateral axis or the extremely low force level, by
   a. Replication of the compression tests at the 0.1 lb. level and perhaps lower.
   b. Replication of the lateral test at the 1 lb. level and perhaps at the 0.05 lb. force level.
2. Determine the effect of surface differences on geometric discriminations with the long cane, in particular on fractionation. There is precedence for this work in the experimental psychology literature.
3. Determine the effect of time variations on geometric discriminations. The time correlate may be as significant as force or distance. Do the blind measure distance with the cane by timing the sweep? Would the introduction of acceleration or acceleration rate affect fractionation?

4. Study of time-variant force interactions transmitted by the cane, and determination of thresholds for various treatments of impulses and vibration - sinusoidal and random, frequency spectrum 20 to 300 cps, amplitudes of 1 mm to 0.001 mm.
5. Determine thresholds of low level compression and lateral force discriminations and distance fractionations using the finger. Is the long cane really the equivalent of a digital extension as far as response to the correlates herein studied?

Application of Conclusions. This study was started to gain some insight in the kinesthetic and tactual stimuli transmitted by the cane. The ultimate use of this information, hopefully, will be to increase mobility for the blind.

The Technical Research Council (13) lists these requirements for a mobility aid:

1. Locate obstacles 10 to 12 ft. ahead, 25° right and left of path centerline, at a walking rate of 5 ft./sec.
2. Give step-down warning of drop-offs exceeding 2 in. at a distance of 6 to 8 ft.
3. Provide information transfer to the brain in a simple manner not requiring an excessive training period.
4. Must not be unduly conspicuous.
5. Perform reliably even in adverse weather.

In addition to this, Hoover (2), mentions the following convenience requirements for the cane:

1. Adjustable length.
2. Light weight and well balanced for reduction in sweeping fatigue.
3. Comfortable handle.
4. Non-catching tip for both crevices and cracks.

One can assume that any research done with the cane ought to lead to either an improvement in the blind man-cane system performance and/or an increase in the convenience of use of the cane without system performance degradation. The latter view requires that some figure of merit for the performance of the cane-man system should be available to the designer so that optimizing the cane for convenience does not adversely affect the system performance based on these figures of merit.

The performance of the long cane used by the blind today satisfies almost all of the Technical Research Councils' requirements, above, reasonably well. The convenience requirements cited by Hoover, above, however, are only moderately satisfied by the long cane. It would also be well if the advantages of a longer cane could be had without the inherent hazards to other people of tripping and bruised shins which are caused by the present rather stiff cane. In addition it would be advantageous to have a cane that could be collapsed to pocket size and yet extendable to a length great enough to give obstacle warnings two paces ahead instead of the present one paçe obtained with the long cane and Hoover technique.

All of the above conveniences are certainly within the capabilities of the designer - providing that they can be combined in a cane without affecting the performance parameters adversely.

(It is not within the scope of this thesis to prove that the force and displacement discrimination levels found here are sufficient as well as necessary to define the performance characteristics of the cane. This would, at present, still be an assumption - certainly not perfect, but probably valid.)

Suppose, then, that in optimizing the cane for convenience, the designer becomes apprehensive about the ability of his cane to transmit the necessary stimuli to the blind

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man's kinesthetic and tactile senses because of an extremely low compression spring constant. It is relatively easy to determine what the threshold of the blind man is with the redesigned cane for any force level between 1 lb. and 10 lb. using a test spring of any stiffness from 1 lb./in. to 100 lb/in. If this threshold exceeds $5\frac{1}{2}\%$ the designer has degraded the performance of the cane - at least for compression forces in the range of interest. By the same token depth fractionation should also be compared to the 10% variability over a 24 in. arc found herein, for the possibity of the loss of depth distance perception with the new cane.

In the future, more parameters may be established which will more closely characterize the correlate transmittance of the cane; but for the present, this is the beginning.

APPENDIX

Distance Discrimination Computation Methods. The method employed in reporting the results of the displacement discrimination test was as follows:

1. x = the distance that each of the 40 determinations per subject per treatment (e.g. Lateral-Shift) missed the center of the arc.
2. $\bar{x}$ = mean miss per subject per treatment
   $= \frac{\sum x}{n}$, where $n = 40$
3. σ = standard deviation of the misses per subject per treatment
   $= \frac{(\bar{x} - x)}{n}$
4. CE = Constant Error for all 6 subjects across each treatment (e.g. Depth No-Shift)
   $= \frac{\sum \bar{x}}{N}$, where N = number of subjects per treatment = 6
5. SD = Variability or mean standard deviation for all 6 subjects across each treatment
   $= \frac{\sum \sigma}{N}$
6. CR = Critical Ratio of the difference in the CE's of the Shift and No-Shift treatments by axis
   $$= \frac{CE_{shift} - CE_{no\text{-}shift}}{\sqrt{SD^2{}_{x\ shift} + SD^2{}_{x\ no\text{-}shift}}}$$
7. SD_x = Standard Error of the sample mean
   $= \frac{SD}{\sqrt{N}}$

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AMERICAN FOUNDATION FOR THE BLIND, INC.

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PROGRESS REPORT

JULY 1, 1960 THROUGH JUNE 30, 1961

(1) IDENTIFICATION:

An International Survey and Analysis of Technical Devices Designed For the Education, Rehabilitation and Personal Aid of Blind Persons

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(2) BACKGROUND:

The American Foundation for the Blind, under the sponsorship of the Office of Vocational Rehabilitation of The Department of Health, Education, and Welfare, has completed the first year of an International survey and analysis of technical devices designed for the education, rehabilitation, and personal aid of blind persons.

In order to marshall adequately the organizations and personnel engaged in work for the blind, the following program purposes were established for this international survey:

(1) An analysis of the results of existing and past avenues and basic premises on which technical research has been founded.
(2) The establishment of the avenues of the physical sciences through which research and development show the greatest potential for the material accomplishment of technical devices for the assistance of the blind.
(3) The collection of a comprehensive library of existing research and technical devices with (insofar as possible) objective evaluations of their respective merits and shortcomings for purposes of dissemination to all present and future scientists, researchers and engineers.
(4) The provision for an intensive and concentrated exchange of scientific opinion and information through national and international symposiums and conferences.
(5) The establishment of a base for more effective coordination among all researchers, through a continuing system for collection, evaluation, and dissemination of developments in the field anywhere in the world.

(3) DEVELOPMENTS:

The past year, which this first annual report will attempt to describe with an economy of means which preserves sufficient detail to insure communication, has been characterized above all by a great diversity. Many sources can be found for this diversity, some stemming from the nature of the study, others inherent in the way the study must of needs be conducted. The nature of the study dictates, for example, that

we must encourage the flow of information to the project from a variety of sources, including university centers of research, industrial centers of research, the activities of individuals engaged not only in research but also in developmental work, and finally the efforts and capabilities of various agencies for the blind, in the United States and also in Europe.* As a natural consequence, there is a great range indeed in the professional and non-professional interests of persons in these various organizations and activities with respect to the objectives of the international survey of technical devices. Finally, the investigators have experienced virtually every environmental surrounding in their meetings with persons in these institutional settings, both here and on the Continent.

One of the questions which immediately comes to mind is: "Is there a danger of distributing one's energies to the point of ineffectuality in this effort to contact so many persons with so many different interests in so many different places?" It is a question which deserves some consideration. We feel, at this point, that our time has been well spent in ranging far and wide in our contacts with persons engaged in both research and applied fields in the application of modern technology to problems associated with blindness. Occasionally we have struck richer veins of knowledge than usual (rather more often than one would suspect), and it is these occasional finds that have encouraged us in our efforts to keep searching, encouraging, and supporting. As we shall point out below, even in some cases where our impression was of rather limited return for our investment of time and effort, we have just begun to realize that the fruits of our labor are most probably of the late-ripening variety, and that the final yield may be high indeed.

It is proposed to treat the developments during the past years under several headings, which it is hoped will help to focus attention on the several aspects of the work undertaken to date in a sequence having both logic and chronological sense. We shall first mention the staffing of the project. The discussion will then cover our attempts to scan the literature relevant to our interests; describe our attempt to develop a universal catalog of devices; review our efforts to gather information on techniques; recapitulate our visits to rehabilitation centers and other private organizations in work for the blind. This first section of the report will cover, in the main, developments which had been in progress at the time of our last report, and although they continue to the present, constitute the first phase of our work. The second part of the report will describe the Scan Column Index, which has been selected for use with the devices catalog; discuss the role of Uniterms and the development of a list of Uniterms for use in the Survey; indicate some revisions in our thinking of the relevance of living systems research to our overall project goals; summarize the results of a visit of the project staff to centers of research in Europe; indicate some additional specific tasks that we have undertaken in the program to develop new information; and, finally, discuss our progress to date in the formulation of plans for the forthcoming International Congress on Research and Development of Technical Devices for the Blind. The report will close with a summary of our plans for implementing and completing some of the items already mentioned in the body of the report, and will indicate our suggestions for continuing the operation of the program to the point where the original goals of the project may be met substantially.

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* The following definitions will apply throughout this report wherever the terms "basic research," "research," "applied research," and "development" are used: Basic research is that type of research which is directed toward increase of knowledge in science. It is research where the primary aim of the investigator is a fuller knowledge of understanding of the subject under study, rather than a practical application thereof. Applied research is that type of research which is directed toward practical applications of science. Development is the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems, methods, or processes, exclusive of design and production engineering.

(a) Project Staff: The original intention of the International Survey was to encourage a fresh look at technical devices from the point of view of modern technology without the possible disadvantages of prior knowledge of and professional work in the field of work for the blind. It was made clear to both the coordinator and the assistant coordinator that the fact of blindness, and the amelioration of the handicaps of blindness, were to be at the forefront of the project, but that it was felt an investigation into some of the more general problems of sensory deprivation and sensory supplantation would probably pay large dividends. In terms of prior acquaintance with the area of blindness, Mr. Holopigian, coordinator, was indeed fresh and unblemished in his approach, while Mr. Clark, assistant coordinator, was tainted only to the extent of some teaching experience on the sociological aspects of blindness as a social problem.* Both investigators have had prior experience in technical areas: Mr. Holopigian was engaged for many years in the design, evaluation, and manufacture of technical and industrial equipment, while Mr. Clark has had academic training in the physical sciences and was project director at Yale University on computer applications to the discursive data of the behavioral sciences.

Bringing investigators into a project such as the International Survey who have had little prior contact with the area of blindness has, we feel, both advantages and disadvantages. Primarily, of course, such a course insures that project personnel have few, if any, *a priori* conceptions of what "should" be done in this area. In the present case, the two members brought with them knowledge of, and contact with, persons engaged in research and development work on the industrial scene (in the case of Mr. Holopigian) and in the academic and scientific community (in the case of Mr. Clark). It should be hastily added that, even so, it has been necessary for us to become acquainted with and to contact many additional persons engaged in a wide variety of technical disciplines in order to insure adequate coverage of the areas of interest to us at present; what is meant specifically by this broadening of contact will become a good deal clearer when we begin to describe our efforts to organize the technical sessions of the forthcoming Congress.

There are some disadvantages attendant to such a course as well. All center about the need to know how work for the blind is conducted on the national level, within the organizations serving the blind, and of course in the various state and local organizations established for the purpose of dealing with the blind directly. Although we can make no claim for exhaustiveness even now, it might be said in all honesty that only now are we fairly well acquainted with principles and practices of agencies serving the blind throughout the nation, in all their diversity, and at many levels of performance. There is, moreover, no short-cut method of acquiring this knowledge of the variety of agency operations through reading and study: the senior investigator devoted the first month or two of the project acquainting himself with the literature of the field after his appointment on July 1, 1960, while the junior investigator caught up with him *in medias res*; nevertheless, we were unprepared for the complexity and diversity of operations in the several states as we found them to be in actuality. We might also add a note of caution for future investigators: we would say that our own experiences (as recorded in our field trip reports) would be of little help, for they are but pale imitations of the complexity and dynamic change characteristic of such operations at the present time. That is to say, there are certain principles of behavior which are, to be sure, constant from one place to another, and these can be spelled out for the neophyte, but there are also no uniform rules of operation of the

* N. Charles Holopigian, Coordinator, International Technological Research Project. University training: B. S., New York University; M. E., New York University.

Leslie L. Clark, Assistant Coordinator, International Technological Research Project. University Training: A. B., Harvard College; M. S., New School for Social Research; M.A., Yale University; Ph. D. candidate, Yale University.

agencies, both public and private, that we visited. Our knowledge of how they do in fact operate is therefore generally on a case-by-case basis.

University and industry-centered research and development programs are, of course, much easier to deal with, and we have concentrated some of our time and interest in these particularly, complementing Mr. John Dupress' efforts as Director of Technological Research of the American Foundation for the Blind. In addition to the field contacts with research personnel made during the course of our visits to the various states, Mr. Clark, after a conference at Massachusetts Institute of Technology, has accepted membership on the Permanent Steering Committee for Automatic Data Processing and the Various Braille Codes, representing the behavioral sciences.

(b) Review for the Literature. As indicated in previous reports, we recognized at a very early stage that we should have to review regularly a rather wide variety of publications for information relevant to technical applications in the field of blindness. We will mention(so that we can pass over) the standard reference works in the field, including Best, Zahl, many AFB publications, and some relevant information in Griffin, Geldard, and others.* Soon after our orientation to the various problem areas in technical applications, we began regular scansion of a series of journals, including:

American Psychological Review
American Sociological Review
Audio
Electronics World
Electronics
Electronics Illustrated
Human Behavior
IBM Journal of Research and Development
Journal of the Acoustical Society of America
Journal of Audio Engineering Society
Journal of the Institute of Radio Engineers
Journal of Speech and Hearing Disorders
Medical and Electronic News
Mechanix Illustrated
Popular Electronics
Popular Mechanics
Psychological Abstracts
Rehabilitation Literature
Science
Scientific American
Wireless World,

plus miscellaneous publications of the Foundation and other agencies serving the blind.

Another source of information has been a bibliography on the sensory apparatus of the human developed by Mr. James Linsner of the Division of Research of the American Foundation for the Blind. Information flow has been in this case two-way, for we have utilized this resource for information, and we have fed information into it when we have encountered something new not already part of its repertoire of data. Additional information has been gathered from the Tufts University Human Engineering bibliography, to which the Foundation is a subscriber through Mr. Dupress' Office.

Best, Harry, Blindness and the Blind in the United States, New York: Macmillan Co., 1934.
Zahl, Paul A. (ed.), Blindness: Modern Approaches to the Unseen Environment. Princeton: Princeton University Press, 1950.
Griffin, Donald R., Listening In The Dark. New Haven: Yale University Press, 1958
Geldard, Frank A., The Human Senses. New York: John Wiley & Sons, 1953.

Finally, we have not hesitated to utilize outside consultants, on both an informal and a formal basis, for review of the relevant literature. In addition to researchers we have contacted for information on literature, we have also in one case hired an outside consultant to present a review of the data now available on front-end (or input) devices for scanning systems and ultimately for reading machines. In the latter case, we were able by a modest outlay to secure from Mr. Samuel Scharff of Eastern Consulting Associates, Inc., data that had already been organized at considerable expense for other purposes by one of the armed services. We have been pleased enough at the results to consider inviting Mr. Scharff to deliver a paper on front-end scanning systems in one of the technical sessions of the International Congress. We shall note in further sections our intention of making wider use of consultants, where feasible, in the future.

(c) Cataloguing of special devices. One of the important goals of the present project is the development of a catalogue of devices intended to alleviate the day-to-day problems of the blind at work and at play. There has long been a need for a rather complete cataloguing of such devices, collating information available not only from the American Foundation for the Blind, but also from counterpart organizations in other countries, and from individuals and organizations developing devices on their own. Moreover, such an effort cannot really ever be considered completed, for innovations are always being developed somewhere of which one learns and must take into account. Our object has been, therefore, to collect all the information we could from currently available sources, and to supplement this with what we could discover in visits with other organizations and individuals, and from published and unpublished (largely correspondence) sources. Accordingly, we have abstracted currently available data from the catalogues of devices produced by the American Foundation for the Blind, the Royal National Institute for the Blind (England), the Deutsche Blindenstudienanstalt (Germany), the Technical Workgroup of the Stichting Technische Voorlichting ten behoeve van Lichamelijk Gehandicapten (Holland), and De Blindas Forening (Sweden). In the latter two cases our knowledge is far from complete, due largely to language barriers in reviewing published information; we did however, obtain some information verbally on our visit to Europe (see below).

Useful information has been obtained from the records files of the American Foundation for the Blind, from published accounts of devices constructed and tested by industrial firms for blind employees, and lastly from patent information. It is in these latter cases that we can say that we have only begun to discover the wealth of information we might seek is buried under nomenclatures which do not correspond in any way with those currently in use. Efforts to uncover information from these sources will therefore be limited by the time we can spare for further searches. We can offer a balm to these troublesome considerations, however, by noting that the information generated by such searches is in the main of historical importance only. It is sobering to realize on review that most of the "radical" proposals for new devices which will allay the handicap of blindness have been put forward not once but several times in the last sixty years, by many different persons in many different occupations. A review of the shortcomings of such proposals, and a study of the reasons why they were not carried further than they were, might well provide some interesting and informative object lessons in research and development problems for some future investigator.

(d) The problem of techniques. It has been our contention from the onset of the project that a technique suitably devised and peculiarly suited in its application was worth more than a device *per se* to the blind individual. Problems of adaptation of instruments and tools, the focusing of attention on one's disability, and complications in distribution and supply of special "gadgets" to blind persons -- all are avoided with the use of a suitable technique. Our interest in techniques has not, however, been met by an equivalent amount in information. One way of getting at the techniques actually used by individuals to solve individual problems is to ask blind persons who have successfully mastered an occupation to tell us how they work and what techniques

they use. Accordingly, we devised, pre-tested, and eventually sent out some 1800 questionnaires to state agencies, with the request that they interview successfully rehabilitated blind workers through their counsellors. Fuller data on the returns will be given in the following section; we need only point out here that very little information of the sort we had hoped to get has come to us through this means.

Our meager store of information was buttressed by the incorporation of data from the Instructional Guide published by the OVR for wood - and metal - working techniques. Cooking techniques have been culled from the General Mills talking book publication for the blind housewife, and we are receiving additional data on household techniques from two state agencies.

The importance of such information to Europeans is, if possible, even greater than to us, largely because far less money is available to most European agencies to provide devices to blind individuals. Hence the emphasis on techniques is greater in Europe and a large amount of information is present and available. We have just begun to tap this source of information through personal contact and by making our European counterparts cognizant of our needs in this respect. It is interesting to observe the reaction of many Europeans when we do ask about the use of techniques, for they are sure that we have so much money available that we automatically provide devices whenever and wherever they are needed, without question and without hesitation. When we explain that this is not always so, particularly for the blind individual, they sometimes seem surprised, then recover quickly to add that they will be glad to provide us with whatever information we need. We are currently collecting such information and will continue to do so during the coming year.

(e) Visits to organizations in the United States. A large block of the time of the investigators was spent, during the first phase of the project, in visiting centers for work for the blind in the various states -- or rather, those with the highest concentration of population and thus the highest concentration of blind persons. Both state agencies and private agencies dealing with the blind were visited, and some university centers of research relevant to applications of technology usually ascribed to the problems of blindness were visited as well. One of the cautions expressed to us before we began making contacts was that although it was not difficult to enlist the enthusiasm of persons in such centers, it often proved difficult to keep them motivated at a level which would insure their continued routing of information we needed to us. As already mentioned, they were asked to adminster a carefully pretested questionnaire to successfully rehabilitated blind individuals through counsellors, and approximately 1800 questionnaires were later mailed out. To date (August 2) we have received but 153 returns, not all of which were properly administered, and in many cases omitting information necessary to make the data most useful. This is considerably below the figure of 750 returns on which we had counted. The only hope we have of morecomplete returns was the expressed opinion of many of the state agencies that they would be unab le to provide us with very much extra time from their counsellors until mid-summer, and the one or two notices we have seen in publications issued by organizations engaged in work for the blind that these agencies are cooperating with us in providing information on devices and techniques utilized by individuals in work and play. In addition to some follow-up letters (which have already been sent out), we plan also to work through some channels available to us at the Foundation (in the Community Services Division) in rekindling interest in completing and returning these documents to us. Certainly data from the field, properly prepared, will offer invaluable information to the counsellors themselves in looking for preferred adaptations or techniques in rehabilitating persons with whom they deal directly, and our proposed publication of this information should prove to stimulate some agencies into action.

(f) Indexing procedures. The elements which will help tie together into usable form the various sources of information and data we have been involved in collecting are three in number, and together constitute a system of information storage and retrieval. The elements are: (1) a card catalogue of 5"x 8" slips containing data on devices, techniques, and relevant information on human perception, cognition, and information utilization data; (2) a set of coordinate indexing terms drawn from the subject matter indexed, (a form of "uniterm"); and (3) the Scan-Column Index, which links together these two parts of the indexing procedure and makes possible the articulation of a low-cost, flexible, and easily reproduced method of getting at information collected. The assertion of a system is based on the facts that no one of these elements is effective alone, and that all three must be used together to retrieve information. In brief these are the three parts of the system:

(1) the content of the 5" x 8" cards. The slips containing information in our files are made up, as mentioned previously, from device catalogues, from published and unpublished research and development material, and from correspondence. In the case of item drawn from catalogues, the file card will contain the name and the class of the device or system; who developed or invented it (where known); the date on which it was available; a description of how it operates; an evaluation of how well it operates (where feasible); and possible improvements which might be made on it (if relevant). In some cases the description on the card will refer the reader to a document file in the project library which contains fuller information or the original description of the device or system for those interested in further information. Each card is also numbered, in order of accession, from 1 on up. Each card also contains indexing terms, as discussed below.

The cards may also contain information on techniques, in which case additional data will be found on the card, including the device or tool to which the technique is referred.

Finally, the cards may contain information relevant to the human factors involved in the operation of such devices and techniques (even remotely), particularly when the devices or techniques are complex. They may contain information on how the "human computer" receives, manipulates and utilizes information generated in the operation of devices which a human uses. Such information may be abstracted from journals, in which case the relevance of the information stored in the system is determined from the outline of the proposed Congress (see Section I). In the case of a summary of information about a particular piece of work on which we have a descriptive document in our project library, there may also be a reference to the library.

(2) indexing terms. Documents in a storage and retrieval system may be indexed in a number of ways, depending on the uses to which the files may be put. Common indexing techniques, such as alphabetical or other ordinal procedures, face immediate limitations when one is interested in some characteristics of the stored documents which is not comprised within the indexing technique. Coordinate indexing techniques are relatively free of these limitations, however, by design. That is to say, a number of indexing terms are assigned to each document in a file, each of them characterizing one or more aspects of the information contained in the document which is stored. Search for documents may then take the form of multiple inquires, each directed toward another aspect of the information stored, and one may also conduct searches for information in terms of conjunctive or disjunctive requests. Thus, one may search for ("scanning systems") and one may also search for ("scanning systems" and " reading machines") in our particular application. In the first instance, one would find under the first term several scanning systems which are applicable only to special-letter reading devices, principally for banks, credit institutions, and the like; in the second

instance, requiring the document to contain both "scanning systems" and "reading machines" would mean that those scanning systems which were of potential usefulness to reading machines would be retrieved along with all data on reading machines. In a similar way, one may conduct disjunctive searches, in which one may request information for "scanning systems" and "reading machines" but <u>not</u> some other characteristic(s), such as "special letter," etc.

Indexing terms themselves may be generated in a number of ways, including taking significant words from the title or contents of a document, as with Uniterms, or by generating synthetic concepts to cover the content of a document, as with common coordinate systems. We have chosen the second approach, for it enables us to create a somewhat more flexible system which will allow us to store material quite outside the nominal concern of blindness but definitely within the purview of our study. Such would be the case, for example, with research (and the results of research) on simulation of the human nervous system, on information handling in the human, and on the operation of the man-machine feedback system.

(3) the Scan-Column Index. This indexing device, invented by Dr. J. J. O'Connor of the University of Pennsylvania, allows the convenient production of a method with which a researcher can enter into the stored information in the card file with the optimum chance of locating information in which he is interested. The Index is constructed by listing all the document numbers which have been assigned to cards along the left-hand margin of a quite wide page. Coded symbols which represent the terms used to index the documents are then located in column to the right of the document number in such a way that in searching for "scanning systems," for example, one would always look for the symbol SS in the column, and almost always in the same column. Thus, one can quite rapidly scan the column on a page, looking for specific information (one characteristic at a time) and locate which documents, if any, contain information relevant to one's interests. Searches involving two or more characteristics are accomplished quickly (up to a maximum of perhaps five or six characteristics at a time), permitting rather complicated conjunctive searches.

No such system is better than the coding used at the very beginning of document-term assignment, of course, and great care must be exercised (as in any indexing operation) to catch most of the relevant aspects of information contained in a particular document (i.e., card). The agreement one makes in using any such system is that one must be willing to expend a relatively large intellectual effort in constructing the system so that search and retrieval times become relatively short.

Finally, no indexing system is any better than the ingenuity of the indexing researcher. It is of course undeniably true that the usefulness of any indexing and retrieval system reflects when it is finished only the most ingenious organization and creativity of the individual who constructed it, <u>at the moment when he felt his work was finished</u>. There may be wholly new combinations of data which prove to be highly significant and which would have resulted in assigning new indexing terms to a document after the index is completed -- but if some review system is not made part of the operation of the system, it will be forever incapable of handling this new insight. Fortunately, the Scan-Column Index lends itself easily to experimentation, first in developing the optimum indexing vocabulary, and second in modifying the system after it has been completed. Documents may be indexed in the Scan-Column Index without themselves being marked or stamped in any way, and modifications of the indexing are thus possible at any time in the future that the researcher cares to review his indexing assignments.

An important feature of the system adopted is that its products can be used by many persons, and there are one or two by-products which may help increase its usefulness still further. As an example, one might note that it will be possible

to reproduce the Scan-Column Index (vis multilith master sheets and suitable reproduction techniques) so that it may be disseminated as widely as desired; every counsellor in an agency for the blind would thus have available to him a way of finding out whether, for example, there was available a tool to do a particular job for a client, or a technique which would serve the same need without special tools; he would also be able to give a thumbnail review of what information was available at that time about any of the class of complex devices intended to aid in mobility or independent reading to an inquirer. The use of the Index might also have the desirable side effect of promoting the usage of a common language among workers for the blind in speaking of technical matters, but we shall not overemphasize this function, for we know of the lack of success of such efforts which they have consciously applied in the past.

As an example of increasing the usefulness of the Index, we might mention the production of a list of Uniterms which describe quickly to an experienced eye the foci of interest in work stressing technological application to problems of the blind. A member of a research facility who saw that the list contained terms indicating our interest in microwave ranging techniques, for example, might be able to refer us to research already done or in progress which would contribute to such applications, and perhaps accelerate such research already initiated in a sensory aids program at MIT or elsewhere. It might also permit technical workers in other countries to utilize basic research facilities in their own countries for our purposes much more effectively. In the case of living systems research, biophysicists and their colleagues who note our interest in information processing in the central nervous system (if we suppose for a moment that this is one of our interests) may well be able to come to our aid with relevant research currently under way for quite other purposes. We can, in this way, hope to promote an economy of purpose both in our own work and in the work of those who labor on our behalf in research centers everywhere in the world.

To date, we have prepared indexing terms for our file cards covering each of the aspects, in moderate depth, covered by the forthcoming Congress (see below), and are now in the midst of preparing the Scan-Column Index from these terms. So far, no retrieval failures have been noted, but as noted below (Part 4) further experimentation will be conducted in the coming months on this aspect of the operation of the system.

(g) Living systems research. Reference has been made several times to our interest in "living systems" or "the human computer," or to "information processing in the human," and the like. A note on our interest may help the reader in understanding our inclusion of this heading in sessions of the forthcoming Congress, and in our inclusion of such topics in our card file and review of the literature. We have mentioned in our previous reports "...the matter of research which is correlative with but not directly related to problems of blindness," and included in this category work in motivational and attitudinal studies, the simulation of living organisms on computers, investigations of the optimum information content for each of the sensory channels, and related matters. Much of the most fruitful research work now under way, in terms of implications for the future development of technology as applied to blindness, proceeds from the unusual back to concrete problems of blindness in much the same way that Freud, for example, studied abnormal behavior in order to understand normal behavior. The basic assumption in Freud's work is that there is a heightening or exaggeration of normal behavior in the psychotic or neurotic which points up features of adjustment to normal life which one might otherwise overlook in looking at the workaday world. Similarly, to ask the question: "How would one code the complexity of living reality so that any relevant datum could be fed into the nervous system of a blind individual?" may help us to ask more searching questions about sensation, perception, and cognition; it may also help others to ask what particular

features of these processes may be utilized, modified, or transferred in order to be most useful to the blind. With the recent renaissance of interest in the living organism as a collection of physical or quasi-physical processes, a new method of thought has been applied to many traditional problems in biology: the idea that studying the living systems from the physical point of view may yield more insight into the operation of physical processes themselves and, by reasoning back afterwards, tell us more about where to look in the living system for information about its operation and maintenance. These new trends, expressed in the many symposiums and conferences in biophysics, space medicine, and in new fields of instrumentation (as in medical electronics), seem to us to be of paramount interest in any effort to survey technical work currently under way which may help us better define the problems we face in devising new and better solutions to problems of blindness, and to help us lead ourselves out of some "blind alleys" into which past applications have led us. It is our belief that with some close attention to developments along these several new frontiers of science we can expect to find a keener awareness of why we have not developed more effective mobility devices and reading machines, for example, so far; we can also expect the building up of a comprehensive reservoir of knowledge about how we perceive, think, and act, which will become of inestimable help in devising new research projects of small but significant scope, each of which will provide us with a new block of knowledge and help us build toward the realization of these and other goals in helping the blind and, indeed, all those with sensory deprivation (and including not incidentally those temporarily deprived, as in a space vehicle). It is impossible to decide, at the present time, just how effective the braille system is, relative to the capabilities of the human being who uses it, because we know so little about what his optimum performance might be with the best combination of tactile stimuli. The March 17-18, 1961 meeting on Automatic Data Processing and the Various Braille Codes (mentioned above), which was sponsored jointly by the Massachusetts Institute of Technology (Research Laboratory of Electronics) and the American Foundation for the Blind, pointed up some basic weaknesses in our understanding of and application of our knowledge of the properties of tactile stimuli in communication. Some searching questions about the best format for braille encoding were asked by participants, questions which will lead to further research, and yet we were all made aware of the gap that still exists between our best scientific talent and those working for the blind in this area -- a gap which must be bridged by much cooperative effort, patience in learning new languages, and understanding of the data from research. No doubt further questions regarding behavioral science research will be raised in this and other areas of braille encoding in the forthcoming Congress to be held on Research on braille at the American Foundation for the Blind in Sept., 1961. We cannot decide on the extent to which we can expect to feed data (and in what form) to the auditory channel without some idea of how much we can detract from its other functions with detriment to the individual. Only now in such progress reports as that of the C.W. Shilling Auditory Research Center (New London, Connecticut) study of the use of auditory cues by the blind for travel, are we beginning to discover some of the data we need in this sensory area. There are many questions such as these to which answers must be provided before we can even state the conditions under which we can expect devices to be adapted ideally to the persons for whom they are ostensibly intended.

We have been implementing this interest and necessity by reviewing, so far as we are able, developments in the fields of human engineering, human factors research, biophysics, and medical electronics, as these are reflected in journals of differing origin, and in conference summaries, papers, and monographs. We have noted also that in several of the European centers of research dealing with

technical applications to blindness, one or more members of technical advisory boards has competence in sensory psychology, applications of electronics in sensory research, or in fields such as automatic control or cybernetics. We have made some arrangements for review of the European data to be summarized for us in these areas to keep current with developments not otherwise reported in the literature.

(h) European field trip. In the original proposal to visit European counterpart organizations engaged in work for the blind, our feeling was that we would, on this first trip, manage at most to make contact with organizations dealing directly with the blind, and that we would have little or no time to develop contact with persons actively involved in research in man machine systems or living systems relevant to our interests. These, we felt, would have to be deferred to a second and later visit. We were, therefore, both pleased and encouraged to find that it was not difficult (indeed quite easy) to penetrate beyond the ostensible function of direct service to the blind to technical workers in these fields of interest to us. In some cases (as in Sweden), the director of the agency was himself quite sophisticated in his appreciation of the role of research in the field of blindness; in other cases (as in England), the staff of the agency included one or more individuals who were responsible for coordinating such research directly with university centers of advanced study; in still others (as in Holland, members of technical advisory committees in the country were themselves researchers working in fields congruent with the foci mentioned above. Perhaps we can refer the reader, then, to the conclusions expressed in our field trip report on Europe (a modified version of which will soon be available for general distribution), as follows: we felt our visits indicated:

(1) that our trip to Europe, far from being the purely exploratory and tentative venture that we had expected, became in fact a stimulating and extremely worthwhile voyage purely in terms of its value to the international survey of technical devices.

(2) We discovered to our pleasure that there is a considerable amount of research now under way or contemplated in Europe of very high quality, and under excellent direction and long-range planning.

(3) We have been able to identify at least a dozen individuals, specialists in the areas of research related to problems of blindness, whom it would be essential to invite as participants in any conference which pretended an international influence and interest.

(4) There are at least three countries in Europe with a conception of the role and conduct of basic research on human perception and cognition in areas related to blindness which are fully equal to the best we can offer. They can, therefore, become full partners in the overall effort to discover new knowledge.

(5) There is need for exchange of information even among and between countries in Europe which are quite near or, indeed, border on each other. Everywhere we went we found great satisfaction on the part of persons we visited and spoke with that at last some responsible organization was willing to undertake the task of coordination of research information that everyone needs and which everyone spends so much time and effort obtaining.

(6) Many European agencies and unions were willing to go even further: to take on responsibility for subsidiary parts of a larger problem, with the overall research responsibility lodged in a centralized information center like our own.

(7) Serious thought should be given immediately to the problem of coordinating information which is beginning to flow from a diverse number of sources;

that the possibilities for coordinating research through some international organ, office, or bureau, are at the ripe psychological moment. There is, many feel, enough to do in conducting research that the additional task of conveying results, evaluating one's research against the work of others, integrating one's products with those of other researchers, and similar tasks, take too much time and trouble for individual workers and single research centers. Serious consideration should be given, we feel, to the establishment of some agency for undertaking these responsibilities on behalf of a de facto research organization in the field of work for the blind and related fields and interests which, even at the moment, comprises centers in most of the free western world.

There is also the question of what part of the total world research picture we have now been able to assess, to glimpse, and in part to evaluate. Once again, we must profess our ignorance of all the data which one would need, to make such an estimate. Based on what we know of the standard of living, aid programs in the various underdeveloped areas, and economic factors operating in the various cultural areas the world over, we would hazard the following statement: the United States and the countries of Europe which we have visited comprise together perhaps ninety percent of the research effort currently under way in the world in areas dealing directly with blindness and indirectly with areas relevant to the amelioration of blindness by technical means. We have not visited Japan, for example, where the phenomenal progress in industrial production in the last fifteen years might lead one to suspect some interest in the development of electronic aids for the blind. There is hardly any doubt, however, that the peculiar and inefficient operation of the Japanese factory -- the reasons for which are an integral part of Japanese culture -- would weigh heavily against industry as a fount of research knowledge, unless direct commercial exploit were somehow involved. In India, any research currently under way would be known to us through St. Dunstan's whose field trial programs constitute the only research there known to us. In these countries, and in the Philippines also, it is possible that there are individual investigators, almost entirely University faculty members, who may be pursuing personal research projects which would fall within our purview; such cases will no doubt become known to us as news of our efforts to coordinate research becomes more widely known. We are also undertaking to advertise our efforts in these areas through our representatives and friends, and through researchers known to us. We have no direct knowledge of work being done, if any, in South America. We do know that in Mexico City there has been work done on the physiological aspects of cybernetic studies; indeed, Dr. Wiener cooperated with this group in the first experiments ever performed. We also know that in Sao Paulo there has recently been established a documentation and information service for the physical sciences, which we will contact for any data we can secure. We are also contacting the National Research Council in Australia for any data we can obtain.

Aside from these rather isolated examples, it is our feeling that there is little effort under way in other areas of the world.

Finally, we would say that, although personality can and does influence the character and operation of agencies fully as much in Europe as in the United States, there was, in every center where research was not an unfamiliar term, a basic willingness to share information and to do work which transcended national and international boundaries, to the resounding credit of the basic spirit of science. It was this fact, above all else, which encouraged us to think in terms of European participation in the common research enterprise on our return to the United States. We have powerful allies in our attack on the problems attendant

to the "technical disability" of blindness. It is up to us to provide that leadership which is necessary to realize the potential awaiting the gatherer, and to discharge the responsibility of seeding potential rich sources of help by broadcasting our interests and our desire to be of help.

I. INTERNATIONAL CONGRESS ON RESEARCH AND DEVELOPMENT OF TECHNICAL DEVICES FOR THE BLIND

Preliminary plans for the International Congress to be held in the United States in 1962 have now been formulated. The Congress will take place in New York City from Monday, June 18th to Friday, June 22nd, 1962. The place of the meeting will be the Barbizon-Plaza Hotel

It is intended to structure the Congress in four parts:

(1) Man-machine Systems
(2) Living Systems
(3) Sound Recording and Reproduction
(4) Adapted and Special Purpose Devices

Panels (1) and (2) will run concurrently, with papers in each of the sessions running throughout the week the Congress is meeting. The latter two panels will be run consecutively, that is, papers on Sound Recording and Reproduction will be presented on the first two days of the week, while the papers on adapted devices will be given during the third to fifth days. There will be, therefore, three concurrent sessions continuously during the period of the Congress. (See below for details.)

In addition to the formal meetings and presentation of papers, present plans call for an opening lunch, a banquet, and a plenary session which may be combined with one or the other of these. All registrants and invited speakers will be invited to these occasions, on which papers will be given on rather general problems associated with technological research. The papers, for which tentative speakers have been nominated, are:

"The Stimulation of Research in the Area of Blindness,"
"The Problem of Research and Development Funding In the United States and Abroad,"
"Coordinating Research and Development: A Critical Review."

With respect to the speakers for these papers (and also for those below) our arrangements are in process, and until we are prepared to announce the completion of arrangements, none of the participants will be named specifically.

Participation in the Congress, particularly at the technical sessions, will be confined by invitation to those actually delivering papers and taking part in panel discussions, although observers will be allowed to the meetings upon specific request. Admittance to the general sessions on adapted and special purpose devices will be open to all those engaged in work for the blind, up to the limit allowed by the auditorium. The meeting rooms for the technical sessions will accommodate about 50 persons, while the meeting room for the larger sessions, including that on sound recording and reproduction techniques, will accommodate about 125 persons.

The tentative outline, subject to changes by session chairmen, attempts to present a program for each session which has, internally, some development of logic in a particular subject area. In each case, chairmen for the sessions have been selected for their acquaintance with and participation in the research which is reported on. We will call on them not only for a general review of the field before papers are presented but also to present a summary of the presentations and discussion in the form of statements of the development of the art at the present time, and the avenues of research which, one can infer from the discussion, are now open for travel.

Panel I - Man-machine Systems

Section I - Guidance and Mobility

1. Opening Remarks: The Meaning of Travel for the Blind. Information Sources, Obstacle Detection, and Orientation.

Techniques of Information Generation.

2. The Cane

Active Energy Radiating Systems.

3. The Bat and Ultrasonic Principles.
4. Ultrasonic Obstacle Detectors.
5. Electronic and Microwave Impulses.
6. Infra-red Ranging Systems and Techniques.

Passive Energy Systems.

7. Ambient Light
8. Summary on the Use of Various Portions of the Electro-magnetic Spectrum.
9. Panel Discussion.

Panel I - Man-machine Systems

Section II - Direct Access to the Printed Page - Reading Machines.

1. Opening Remarks: Review of Development; the Major Functional Components of Reading Machines.

Simplex Systems

2. Battelle Reader, Optophone, and Other Related Devices.

Complex Systems

3. Letter Scanning and Character Recognition: Principles and Applications.
4. The Logic Function Component.
5. Audible Output to the Reader.
6. Tactile and Kinesthetic Output to the Reader.
7. Problems of the Design of Whole Systems in Reading Machines.
8. Summary by the Chairman and Panel Discussion.

Panel I - Man-machine Systems

Section III - Direct Access to the Printed Page: Punched Paper Tape, Punched Card Translation and Duplication.

1. I.B.M. Stereotype Systems.
2. Creation of Braille Punched Paper Tape Control Systems.
3. Reproduction of Braille from Existing Punched Paper Tape Systems.

4. Problems of Standardization of Punched Paper Tape Control Systems.
5. Summary by Chairman and Panel Discussion.

Panel II - Living Systems

Section I - The Mechanisms of Seeing and the Characterization of Sight.

1. Opening Remarks: Blindness as a Technical Disability (Instrumentation Problems in Blindness and their Similarity to Instrumentation Problems in Space and Underwater Navigation Research).
2. The Mechanisms of Seeing and the Characterization of Sight.
3. Mechanisms of Seeing: Information Flow in the Visual Channel.
4. Mechanisms of Seeing: Parameters of Vision.
5. Mechanisms of Seeing: The Role of the Brain.
6. The Characterization of Sight: The Differential Role of Sight and Memory in Vision.
7. Organic Reconstruction and the Question of Organic Transplants.
8. Panel Discussion.

Panel II - Living Systems

Section II - Utilization of the Remaining Sensory Channels.

1. Translation of Visual Data to Auditory Data.
2. Training the Aural Sense to Greater Usefulness.
3. Summary of Applications and Gaps in our Knowledge of Audition.
4. The Possibility of Reducing Redundancy in Speech.
5. Applications of Tactile-Kinesthetic Translation; Gaps in our Knowledge for Maximum Utilization of this Channel of Information Flow.
6. Summary by Chairman and Panel Discussion.

Panel II - Living Systems

Section III - Correlative Research.
The Simulation of Living Systems.

1. Relevant Research already in Progress.
2. Suggested Avenues for Future Exploration.

The Question of Direct Coded Input of Data to the Brain.

3. Conceptual Difficulties in Such Applications.
4. Possible Solutions of the Apparent Difficulties.

Electroencephalographic and Electroretinographic Studies.

5. The EEG, the ERG, and Blindness.
6. Comments by Chairman and Open Discussion.

Panel III - Sound Recording and Reproduction.

Section I - The Disc Talking Book.

1. Status Report on European Usage.
2. Status Report on the United States Position.

3. Extension of Practice to 16-2/3 and 8-1/3 RPM Recordings; Future Prospects of the Disc Talking Book.
4. Cost Analysis of a Disc Talking Book Program.

Section II - The Tape Talking Book

5. The English Cassette System.
6. The Proposed Library of Congress Cassette System.
7. The Tape Talking Book in Continental Europe.
8. The Problems of Tape Duplication.
9. Commercial Developments in Tape Cassette Systems.
10. The Question of a Cost Analysis for a Tape Talking Book Program.
11. Problems of Standardization in the Talking Book Programs.
12. Discussion and Summary by Chairman.

Panel IV - Adapted and Special Purpose Devices.

1. Opening Remarks: Adapted Devices and the Use of Techniques.

Section I - Education, Reading, Writing.

2. Braille Embossing Systems.
3. Braille Solid Dot System.
4. Small Quantity Braille Reproduction.
5. Hand Braille Writing Equipment.
6. Adapted Calculators; Abaci, Soroban
7. Other Educational Aids.

Section II - Vocational Aids.

8. Adapted Devices for Measurements - Electronic and Other.
9. Adapted Devices in Industry.
10. Adapted Devices for the Individual Craftsman.
11. Adapted Devices for the Household.
12. Adapted Devices for Clerical Workers.
13. Adapted Devices for Mercantile Craftsman.

Section III - Recreation and Comfort. Devices and Aids.

14. Toys, Games, and Other Devices.
15. Adapted Devices for the General Comfort of the User.

Section IV - Techniques.

16. Work Techniques in the Household.
17. Work Techniques for the Individual Craftsman.
18. Work Techniques for the Clerical Worker.
19. Work Techniques for Tradesmen.
20. Work Techniques in Industry.

Arrangements will soon be completed to handle the shipping, installation, protection, and reshipment of all devices, equipment, and machinery needed by participants for demonstration purposes and for exhibition at the Congress. It is expected that an exhibit area will be available for use adjacent to meeting rooms and auditorium, so placed that it will receive maximum exposure to Congress traffic.

(j) Miscellaneous. In the course of our work during the past year, we found from time to time that there were gaps in knowledge and/or information which, we felt we could at least start building bridges to cross. Some of these grew out of specific requests made of us by persons to whom we spoke of our work; others evolved as our investigation proceeded, and we felt the need to supply the data to those who needed it. The following listing does not represent any particular order for these projects or rather subprojects) for they are all current:

(1) the potentialities for plastic cane tips. A specific request, received from one of the state agencies, initiated our interest in suitable replacements for the common steel tip used currently on lightweight canes; curiously enough, we received several requests from other individuals, including some from within the Foundation, after that time. We have written to several major plastic products manufacturers, especially those with experience in re-entry ceramics and similar materials, and so far have received complete technical data and samples of rods from two of these. The Foundation laboratory and shops are now preparing sample cane tips made from DuPont nylon resin rods and GE "Lexan" polycarbonate resin rods. After fabrication of the sample cane tips, we will conduct limited field tests with Foundation personnel and, if the results look promising, will extend these tests to persons outside the Foundation.

(2) index of master craftsmen. One of the most vexing problems in adapting a production line job to a blind worker is the selection of the most appropriate tools to do a particular piece of work, when these tools are not standard on the line. The procedure followed currently consists largely of a "cut and try" method which attempts to evaluate informally the effectiveness of a particular tool to do a particular job until a suitable tool is found. In conjunction with the Oakland (California) Rehabilitation Center, we are attempting to shorten this period of experimentation and to make available the results of trial and error. The method we are following consists in the development of an index of master craftsmen for the 360-some odd crafts currently listed by the United States Department of Commerce, Bureau of the Census. So far, we have obtained listings of apprenticeable trades in New York and in California, and are preparing to contact the various craft councils for some idea of likely candidates for the index of master craftsmen. When the index is completed, our intention is that, if it is discovered that there is a new production task problem for which the most suitable tool is not known, we can describe the tooling requirements to our cooperating master craftsmen, and receive from them suggestions of the most appropriate tool and/or technique for doing the job. As Mr. Jenkins of the Oakland Center has indicated, there are many "tricks of the trade" used by master craftsmen not normally communicated through usual channels which might indeed make some jobs easier for blind persons, and we are eager to collect this kind of information. The information gap here is similar of course to that which we face in obtaining information on techniques; indeed it may be the same problem from another point of view.

(3) rational braille. In the MIT conference on automatic data processing and the various braille codes, it was suggested by Professor Baumann that current forms of braille are difficult to encode for automatic data processing and automated production of braille in part because of the series of historical accidents which have fixed braille in its present coded form. This opinion was shared by several others. There might be, he suggests, alternate ways of coding tactile information, similar to braille, which would make for easier rules for computers to follow, and at the same time realize some gains in compactness; both of these follow from the result of increasing the density of information in the braille symbol, or the number of bits per tactile stimulus. Since one of the project members has accepted appointment to the Steering Committee established at the conference, as indicated above, we have devoted some time to attempt to realize some of these benefits in an experimental version of a rationalized braille coding system. As a first step, we are trying to do two things: first, to distribute the braille codings, of both letters and contractions, according to the actual occurrence of these symbols in English text; second, to test the internal consistency of the rules of braille from the point of

view of Boolean tests of logic, in order to insure the absence of conflicts and contradictions. So far, we have got about halfway through the first task.

(4) demonstration tapes. During our visits with agencies for the blind and with research workers too, we received a number of requests for the provision of two types of taped data: the first was some representative selection of papers illustrating problems in the area of human factors influencing the design of mobility devices and reading machines, and the second was a representative selection of the actual output of the reading machines devised so far. The first of these has now been prepared, and some copies already distributed; it contains a summary of the report on "spelled speech" output for a potential reading machine developed by Dr. Metfessel of the University of California; the latest report report from the Battelle Memorial Institute (Columbus, Ohio) on the Battelle reader (1961); and the article by Dr. Shipley of American Optical Company (Rochester, New York) on the possibilities for direct coded input of visual data into the human brain. The second tape will contain recorded examples of the audible output of (a) the British Optophone, (b) the Battelle reader, (c) the Argyle reader (Canada), and (d) the Aronson reader (California). We are now writing a script for these demonstrations which will stress the uniformity of these various approaches, and will also point out the differences among the various forms which these probes have taken; it is our plan also to include some technical description which will indicate the specific forms which the circuits have taken to provide the output for each device. This tape is desired especially by several European investigators who complained that they had never had an opportunity to hear such devices, and thus have had to rely wholly on written accounts of them for evaluation.

(5) publications. In addition to a large and active correspondence, project members have written the following:

1) "International Survey of Technical Devices," New Outlook for the Blind, Vol. 55, No. 6 (June, 1961), pp. 216-219.
2) Questionnaire and Instructions to Interviewers: Devices Study (1961), 7 pp.
3) First Progress Report and Publicity Release: International Technical Devices Survey (1961), 7 pp.
4) Format for Summary File Document Cards for Technical Devices Survey (1961), 7 pp.
5) Uniterm Listings for the Physical Sciences (Preliminary Version) (1961), 5 pp.
6) Uniterm Listings for the Behavioral Sciences (Preliminary Version) (1961), 6 pp.
7) Outline of the International Congress on Technical Devices, 8 pp. (included in this report).

(6) translation. After the visit of the young physicist, Mr. H. Kazmierczak, of the Technische Hochschule of Karlsruhe, a version of his since many of those whom he visited in America have not yet seen his report, and many others cannot read German, we felt that it would be useful to have an English version prepared for general distribution. This plan was approved by Mr. Kazmierczak, and we are in the midst of translating his very stimulating report, which is sure to arouse some controversy because of its pessimism.

(4) PLANS

The reader may well infer from all the foregoing that we face a busy schedule in the coming year in our attempt to bring the various strands we have been weaving into a whole cloth at the conclusion of the second phase of our project. Indeed, in each of the developments that have been discussed, it is quite clear that quite a good deal yet remains to be done, and our plans would thus reiterate much of what has already been said. In addition to the increased use of consultants to accomplish much of what we see needs to be done, we would therefore proffer the following list, abstracted from our previous discussion of the major goals of the project for the coming year:

(1) Preparation of papers to be distributed at the International Congress on Technical Devices;

(2) The actual execution of the Congress in its many aspects;

(3) The preparation of an "index of devices and techniques," to be distributed to field workers dealing directly with the blind;

(4) The preparation of the Scan-Column Index, to be distributed not only to field workers, but also to researchers in man-machine systems and living systems research and development;

(5) The editing of a concluding monograph issuing from the Congress, including additional papers, introductory and explanatory material, etc.;

(6) Establishment of a center for information collection and storage;

(7) Establishment of a system for passing of data to and from research personnel to persons and agencies engaged in work for the blind, and the expansion of the system to encompass all relevant research data.

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